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PROCEEDINGS OF FIRST NATIONAL CONFERENCE ON THE PEACEFUL USES OF SPACE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION U.S.A.

TULSA OKLAHOMA MAY 26 27, 1961

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FIRST NATIONAL CONFERENCE

ON THE

PEACEFUL USES OF SPACE

TULSA, OKLAHOMA MAY 26–27, 1961

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DEMARQUIS D. WYATT—Director of Programs, NASA.

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OPENING STATEMENT

PRESIDENT JOHN F. KENNEDY

Gentlemen, ladies. I appreciate this opportunity, at the invitation of Senator Kerr, who is Chairman of the Space Committee of the Senate, to open the First National Conference on Peaceful Uses of Space. And I regret very much that I am unable to participate personally in this conference and in the discussion in which you will be engaged. Your conference subject deals with the very heart of our national policy, in space research and exploration, to which I devoted a good deal of my speech yesterday before the Congress. All of us in the United States and in all nations can derive many benefits from the peaceful application of space technology. The impact of this new science will be felt in our daily lives. It can bring all people closer together through improved communications. It can help control the weather and the climate around us. We can safely predict that the impact of the space age will have a far-ranging effect within industry and in our labor force, on medical research, education, and many other areas of national concern. The keystone of our national policy is space research, as defined in the act which established the National Aeronautics and Space Administration, whose function is "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere."

These are the words in the act of the Congress, "the preservation of the role of the United States as a leader." And it is to meet that great responsibility that I have suggested a great national effort in the field of space for the American people. We are dedicated to the accomplishment of this objective and are determined that this Nation will continue to be a pioneer in the new frontier of space.

I am delighted that the people of Tulsa have taken the initiative in the heart of our country in making this important meeting possible, and that the response has been so widespread. It indicates the forward spirit of this city and this state and our country. And I hope this conference will establish a precedent as the people of America move forward into space.

NASA SPACE FLIGHT PROGRAMS

ABE SILVERSTEIN, Chairman
MILTON B. AMES, JR.
WERNHER VON BRAUN
EDGAR M. CORTRIGHT
HAROLD B. FINGER
ROBERT JASTROW
GEORGE M. LOW
ALFRED M. MAYO
DEMARQUIS D. WYATT

NASA SPACE FLIGHT PROGRAMS

1. IMPACT OF SPACE RESEARCH ON THE SCIENCES

by ROBERT JASTROW*

Space research is a vigorously expanding field, and growing even more rapidly than nuclear physics did in the years after the Second World War. We have in fact developed an entirely new area of research to a very high level of activity in the short space of three years: In 1958, a typical scientific monthly, the *Journal of Geophysical Research*, printed five papers on space research, while in 1960 the same monthly printed no less than 120 papers in this field.

This phenomenal growth stems from the availability of rockets and spacecraft that can carry apparatus weighing several hundred pounds into orbit above the atmosphere or out into interplanetary space. These spacecraft permit us to obtain data that we could not get on the ground. They open up new avenues of attack on some of the most important problems in science—problems related to the manner in which the Sun controls the atmosphere of the Earth; to the structure of the Earth, the Moon, and the other bodies in the solar system; to the origin and history of the solar system; and to the structure and evolution of stars and galaxies.

Our Government and our scientists are responding to these opportunities with a remarkable display of energy and imagination. In a series of 19 elaborately instrumented scientific satellites and space probes launched during the last three years, we have examined the properties of the upper atmosphere and its extension into the interplanetary medium, and unraveled the complex and significant history of the relation between atmospheric properties and solar eruptions; we have taken photographs of the Earth from above, which reveal patterns of organization in the cloud cover extending over areas of hundreds of thousands of square miles at one time, and promise to produce rapid advances in our ability to predict weather; we have charted the deviations of orbits of satellites from their expected paths, determining thereby the irregularities in the gravitational field of the Earth, and acquiring an understanding of the structure of our planet in its deep interior that could not be gained by surface means; and most recently we have launched a gamma-ray telescope into orbit, designed to reveal the sources of energetic radiation in the sky, sources that have been hidden from us until now by the blanketing effect of the Earth's atmosphere.

In order to understand why these projects are of such fundamental scientific importance, we must be acquainted with the description of the physical world that has developed out of the advances of science during the last 50 years. It is a description of remarkable simplicity, according to which every complex object in the universe is constructed out of just three fundamental building blocks, and every event that occurs in the natural world is governed by the actions of just three fundamental physical forces.

The fundamental building blocks of the universe are the neutron, the proton, and the electron. The neutron and proton are bound together very tightly by nuclear forces into a compact mass, which constitutes the atomic nucleus. Electrons revolve around the nucleus, bound to it by electrical forces, and the electrons and central nucleus together form the atom. Atoms in turn are cemented together to form solid matter (fig. 1).

*Director, Space Sciences Institute, National Aeronautics and Space Administration.

The Earth is a large collection of such atoms cemented into solid matter; it and the other

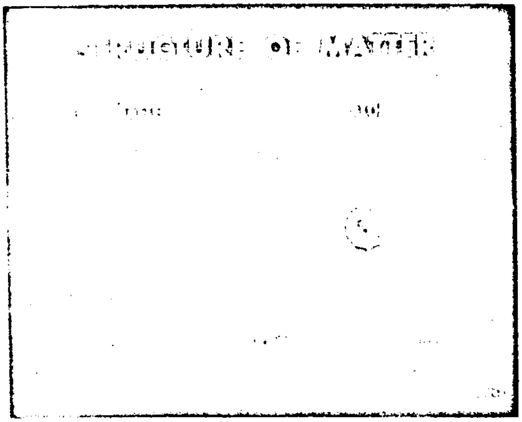

FIGURE 1

planets are all bound to the Sun by the force of gravity, and revolve around the Sun in much the same way as the electrons revolve around the nucleus of the atom (fig. 2). The Sun is

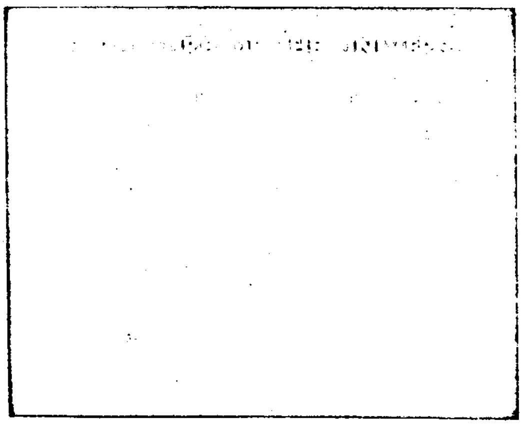

FIGURE 2

one of 100 billion stars, which are bound together by gravitational forces into a disk-shaped mass called a galaxy. We can see the cross section of this galaxy whenever we look up into the sky at the Milky Way. The galaxies tend, in turn, to collect into large clusters, each containing on the average about 1000 galaxies. These clusters of galaxies together make up the universe, according to current ideas at this junction in the development of science.

This is the hierarchy of structure in the natural world. It is remarkable that the progression in size and complexity, from the smallest subnuclear particles to the galactic clusters, is built on only a few basic forces of nature.

First and most powerful is the nuclear force, which cements neutrons and protons together into the tightly bound nucleus of the atom. Because this force of attraction is so strong, the nucleus is extremely compact; it has a density of one billion tons per cubic inch.

Next is the electromagnetic force, which is approximately 100 times weaker than the nuclear force. The electromagnetic force binds electrons to the nucleus to form atoms, and binds the atoms together into solid matter.

Least powerful is the force of gravitation. The gravitational force is exceedingly weak, about 10^{40} times weaker than the nuclear force. Nonetheless, it is this very frail agent that keeps the Moon in orbit around the Earth, the Earth and other planets revolving around the Sun, and the Sun and other stars clustered together in our galaxy.

Strangely enough, the birth of the stars depends on the interplay between the forces of gravity and the nucleus—the weakest and the strongest forces in nature. According to the best evidence, stars are formed out of accidental condensations arising in the swirling and turbulent motion of the gas and dust that pervade outer space. When a condensed region develops by chance in some part of outer space, the particles in the region are drawn still closer together by the attractive force of gravity, and the condensation develops until eventually the entire mass is highly compressed. This takes about 10 million years. The compression causes the center of the cloud of gas and dust to become quite hot, reaching a temperature of about ten million degrees.

At such high temperatures nuclear reactions can ignite spontaneously. In these reactions, the hydrogen nuclei at the center of the dust cloud combine to form helium nuclei, releasing at the same time enormous amounts of energy. The energy generated by these nuclear reactions is great enough to keep the star from collapsing further under the force of gravity, and it lives out the rest of its life in a precarious balance between nuclear and gravitational pressures.

The release of nuclear energy incidentally provides the source of the light by which we see the star.

The process by which hydrogen nuclei combine to form helium is called thermonuclear fusion (fig. 3). It has been duplicated on Earth in the explosion of hydrogen bombs, and attempts are also in progress to produce it in the laboratory under controlled conditions.

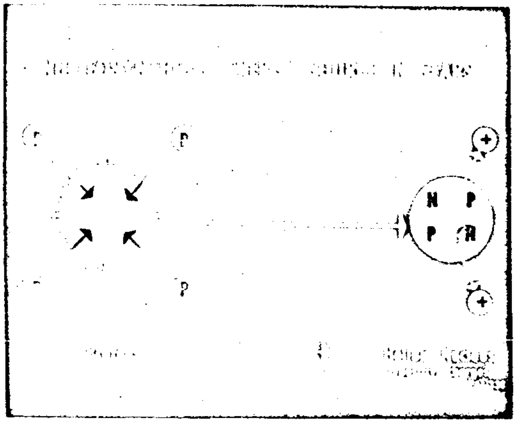

FIGURE 3

Astronomers and physicists have come to the conclusion that this reaction that goes on in newly born stars is the first step in a cooking process in which all the elements of the universe are synthesized out of hydrogen as the basic building block. As the burning continues at the center of the young star, the hydrogen is gradually replaced by helium, until eventually helium becomes the dominant constituent. Since, in this nuclear reaction, hydrogen is the fuel and helium constitutes the ashes, when a large amount of helium has been produced, the burning process or star-fire is smothered to some degree and slows down; when that occurs, the star begins to collapse again under the force of gravity. The collapse produces a further compression and increase in temperature at the center of the star, until the core becomes so hot that the helium itself starts to burn. With the burning of helium, the fire is renewed at the center and the gravitational collapse is halted.

The burning of the helium consists in the combining of three helium nuclei to form the single heavier nucleus of carbon. This fusion of helium nuclei into carbon is again accompanied by the release of a large amount of energy. When a substantial fraction of the helium has been converted into carbon, the next stage of burning begins, and in this way successively heavier elements are built up from the original hydrogen.

However, when the critical element of iron is reached, the process halts. The iron nucleus is approximately halfway between the lightest and the heaviest elements in nature, and it is also the most stable of all elements. It absorbs energy instead of releasing it, and severely damps the reaction. In fact, it puts out the fire, and when this happens the star collapses completely under the force of gravity. The collapse produces enormous pressures and temperatures, and these conditions cause an explosion in which the star is blown apart.

The explosion marks the end of the star's life. It is all over very quickly, the collapse of the star from the initial radius of a million miles or so occurring in a matter of seconds. That is a short time for the demise of an object that has lived some 10 billion years.

Almost all the matter of the star is ejected into space by the explosion, including the heavy elements the star has been manufacturing during its lifetime. After the explosion these heavy elements mix with the hydrogen gas in the space between the stars, and in the course of time new stars condense from the enriched mixture of gas and dust, as we described previously. Thus, the life history of the star is a cycle of dust to dust, from birth out of the condensation of interstellar matter to final destruction by collapse and explosion.

The exploding star is called a supernova. Such exploding stars are extremely bright; they may be as much as one billion times brighter than the Sun.

About 50 supernovae have been photographed with telescopes in the last 75 years. In our own galaxy, only a few occur every thousand years that are bright enough to be seen by the unaided eye. The earliest reported supernova was the brilliant explosion recorded by Chinese astronomers in 1054 A.D. At the position of this supernova there is today a great cloud of gas known as the Crab Nebula, which is expanding outward at a speed of 1,000 miles per second.

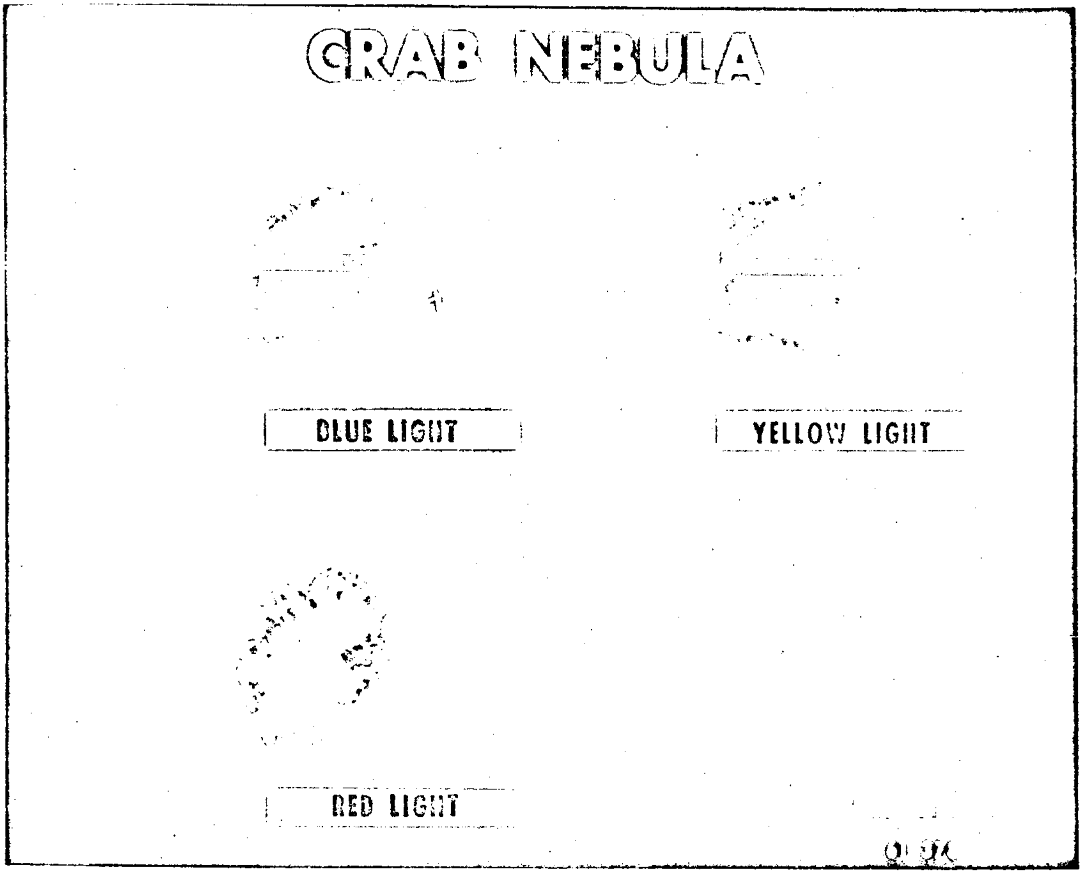

FIGURE 4

This nebula is believed to be the remains of the explosion of 1054 A.D.

It is very important to notice that these Crab Nebula photographs (fig. 4) were taken in several colors, including the infrared, but excluding the ultraviolet. The ultraviolet photograph is missing because ultraviolet light cannot penetrate the atmosphere. In fact, the atmosphere filters out a large part of the radiation emitted by the stars. Only the visible region and a part of the radio spectrum can get through to the ground. This is extremely unfortunate, because the light from the stars provides our only contact with the distant regions of the universe. This light is collected by large telescopes and analyzed to tell us the constitution, the temperature, and the other basic characteristics of the stars and the gas and dust in space. That is how we obtain the knowledge we now possess regarding the universe around us.

Yet, because of the absorbing effect of the atmosphere, the information that we can collect on the ground in this way is only a pitifully small fraction of the total that would otherwise be available. The space program now provides us, for the first time in the history of science, with the possibility of collecting all accessible information about the stars, by sending a telescope into orbit above the atmosphere. The project requires the mounting of this large and delicate instrument in a satellite, the development of accurate and reliable methods for pointing it at specific stars under remote control from the ground, and other extremely formidable engineering problems; but the orbiting telescope will be so valuable a source of other-

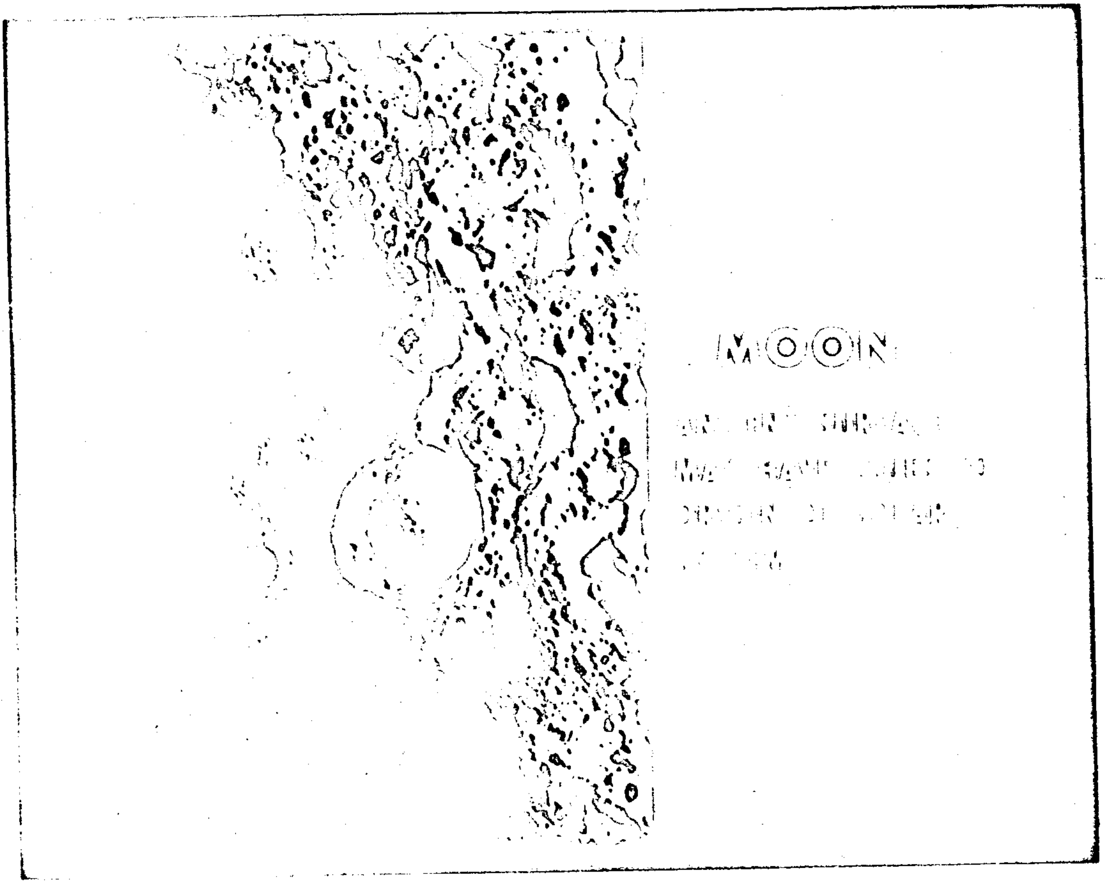

FIGURE 5

wise unobtainable information that it has been given a very high priority in the science program of the NASA. When the satellite telescope is launched into orbit, it will be a giant step forward in astronomy, and one of the most important contributions that the space program can make to science.

Another problem to which the space program can make a unique contribution is the question of the origin of the solar system.

We know that the solar system was formed about 4.5 billion years ago, but we do not know how it was formed, and this problem has been the subject of much thought and speculation for centuries. The investigation of the origin of the solar system by instruments carried to the Moon and planets in space-flight vehicles is a project of the greatest scientific importance and general interest.

The Moon plays a special role in this investigation, because it is a body whose surface has preserved the record of its history for an exceptionally long time (fig. 5). On the Earth, the atmosphere and the oceans wear away surface features in 10 to 50 million years. Mountain-building activity turns over large areas of the surface in about the same time. There is little left on the surface of the Earth of features that existed several hundred million or a billion years ago, and the same is probably true of Mars and Venus, whose properties resemble those of the Earth. But on the Moon there are no oceans and atmosphere to destroy the surface, and there is little if any of the mountain-building activity that rapidly changes the face of the Earth.

For these reasons the Moon has retained a record of its history that probably extends back through many billions of years to the infancy of the solar system. To the student of the early history of the solar system, the Moon is even more important scientifically than Mars and Venus.

The internal structure of the Moon can also provide clues to the origin of the solar system, quite apart from the study of its surface features. One of the theories for the formation of the planets, which was popular until recent times, held that they were created during a near collision between our Sun and another star, in which the gravitational forces between these two massive bodies tore out huge streams of flaming gas (fig. 6). As the second star receded, the

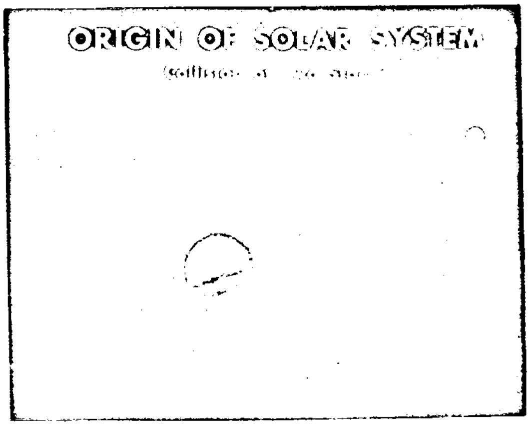

Figure 6

masses of gas that happened to be near the Sun were captured by it into orbits in which they eventually cooled and solidified to form the planets.

If such a collision were the way in which the solar system was formed, then the Moon and the planets must have been very hot at an earlier stage in their histories. In that case, the heavy elements in their interiors would melt and run to the center to form a dense core. Iron is the most abundant of the heavy elements, and all planetary bodies would therefore have iron cores, according to this theory.

Another theory holds that the planets were formed out of condensations of gas and dust around the Sun (fig. 7). We know that stars themselves are probably formed in this way, by the condensation of interstellar gas and dust. It seems likely that smaller condensations would

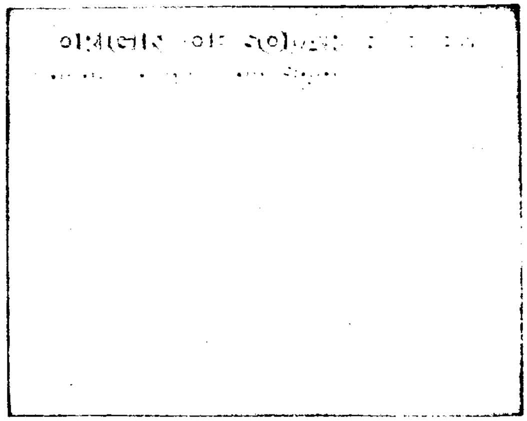

Figure 7

develop in the cloud of dust around the primitive Sun during the early stages of its lifetime, before all the surrounding material had been drawn to the center by gravity. The Moon and planets would then have been formed out of these subcondensations.

If the Moon and planets were indeed condensed out of cold gas and dust, then the iron in their interiors would not necessarily melt and flow to the center. Planets as large as the Earth might be expected to melt completely, as a result of the heating due to decay of radioactive elements in the interior, and thus to develop iron cores in any case. But the Moon is smaller and colder, and if it were formed cold, enough heat would be lost from the lunar surface to keep it from melting subsequently. As a result, the Moon would not form an iron core, but would retain a structure in which bits of iron are distributed through the main body of rock, like raisins in a fruitcake (fig. 8).

During the lunar-exploration program, we hope to study this and other questions related to the internal structure of the Moon, by landing on its surface instruments of the kind used to study the interior of the Earth. Earthquake records have been the source of most of our information on the internal structure of the Earth, and they were the means by which we discovered that the Earth has a liquid core. An instrument for detecting earthquakes will therefore be the first instrument to be dropped on the surface of the Moon, in our lunar-exploration program, as a part of the forthcom-

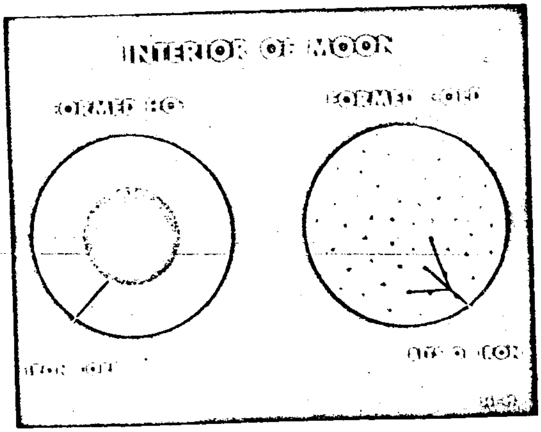

FIGURE 8

ing series of flights with the Ranger spacecraft in the next year or so.

A third problem of major importance in the space program is the study of the control exerted by the Sun over the atmosphere of the Earth.

We know that the surface of the Sun boils and bubbles actively, ejecting huge clouds of charged particles and streams of X-rays into the space between the Sun and the planets. These solar eruptions are known as flares. If the flares occur in the right position on the Sun's surface, the clouds of charged particles are ejected toward the Earth and travel across space to collide with our atmosphere. Although the energy carried by these solar particles averages less than one millionth of the energy radiated by the Sun in the form of visible light, and their effects are usually not noticed by the man in the street, they can, nonetheless, be very important. They produce communications blackouts, magnetic storms, and auroral displays; and they also produce violent changes in the intensity of the Van Allen belts, which are apparently related, in a manner not yet clearly understood, to the other atmospheric effects that accompany solar flares.

The entire matter of Sun-Earth relations, including the formation of the Van Allen belts and their possible role in geophysical phenomena, constitutes a relatively new area of research in the space sciences. It is an area that was greatly stimulated during the International Geophysical Year by Van Allen's discovery of the radiation belts that bear his name, and that is, at the moment, the most exciting and fruitful field of research in the space-science program.

In the great flares of 1960 we obtained for the first time an understanding of the complete sequence of events during one of these eruptions. These were the flares at the end of March, in September, and in November of 1960. At various times during these events we had the Explorer VII satellite in orbit near the Earth, the Pioneer V spacecraft out in interplanetary space, and a large number of experimenters simultaneously taking observations on the ground.

The combination of the space-flight data and the ground observations revealed a fascinating picture. It appears that a tongue of plasma (i.e., of relatively slow-moving charged particles) erupted from the surface of the Sun at the site of the flare, and moved out across interplanetary space at a speed of about 1000 miles per second. At this rate it took the plasma cloud about one day to reach the Earth. The cloud dragged with it lines of solar magnetic force, which were frozen into the cloud and forced to move with it by the laws of electromagnetism. These lines of magnetic force had their roots on the surface of the Sun in the vicinity of the flare, but as the plasma tongue moved across space they were drawn out with it like loops of taffy (fig. 9).

When magnetic-force lines become distended in this manner, they lose their strength; and

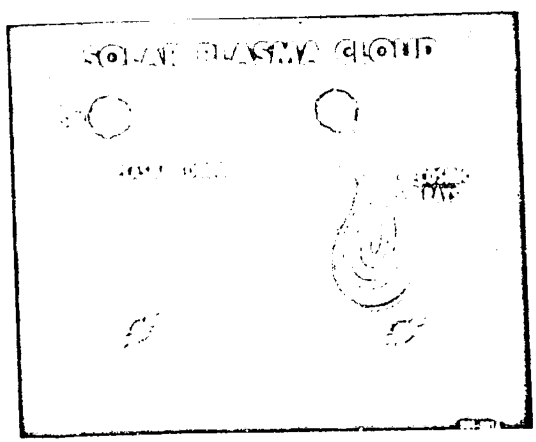

FIGURE 9

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by the time these reached the Earth, they were some 500 times weaker than they were at the surface of the Sun. However, the magnetic field within the plasma tongue was still sufficiently strong to screen the Earth partially from the cosmic rays that normally bombard it. The screening effect is called a Forbush decrease, after Forbush of Carnegie Institute, who discovered it about ten years ago. During the solar events of March and November 1960, the Forbush decrease was observed simultaneously on the Earth, in the Explorer VII satellite, and in the Pioneer V spacecraft. The magnetic-field variations were also observed at the same time, both in interplanetary space and on the ground. By combining these observations in space and on the Earth, we were able to determine the cause of the Forbush decrease and to construct this picture of solar eruptions and their influence on the Earth's atmosphere. This is a major step forward in the understanding of Sun-Earth relationships, and one that represents, better than any other project at the present time, the rapid progress that spaceflight vehicles can bring to scientific research.

But the value of the space-science program is not limited to its intrinsic importance in revealing the laws that govern the physical world. It also plays an essential supporting role in the programs for manned space flight and for satellite applications.

In the program for manned flight, human experience will be extended to new and initially hostile environments whose unknown hazards must be discovered and controlled. For example, the first major discovery of the space program in basic science was the Van Allen radiation belt, which plays such an important role in our gradually developing understanding of Sun-Earth relationships; but Van Allen's discovery also revealed at the same time a previously unsuspected danger for man in space.

As a second example, the streams of fast particles emitted from the Sun during flares are one of the most interesting and most important scientific discoveries to come out of the space program during the last year; yet these particles are, again, a hazard to space travel, and even more dangerous than the Van Allen belts to the future occupants of manned spacecraft.

We are making progress in this study of solar activity, and with a strong continuing effort we should be able to predict the occurrence and control the harmful effects of these solar outbursts.

The support of manned flight is also an essential element in the motivation of the lunar program. This program is designed to study the surface features and composition of the Moon's surface, in part for the clues they can provide to the history of the solar system; but the same study will also provide the data needed for manned lunar landings: the mapping of the surface for navigation across the lunar terrain; and the analysis of composition for minerals, water content, and other constituents that may contribute to the life support of manned lunar bases. In these and other ways the full spectrum of activities in the scientific program will contribute to the accomplishment of manned space flight.

In addition, in the course of the next several years the space-science program will provide important support to our satellite projects in the fields of weather forecasting and communications. The weather-satellite program is related in a particularly direct manner to the NASA program of research in the atmosphere and ionosphere. The problem of weather forecasting is to predict the response of the atmosphere to local variations in the absorption and reradiation of solar energy over the surface of the globe. These variations in the transfer of radiant energy produce temperature and pressure differences over land and sea areas, differences that are balanced by the generation of wind, clouds, rain, and all the other phenomena that collectively compose the weather. But the study of this problem requires an understanding of all the factors that go into the determination of atmospheric conditions; for the atmosphere is a single system in which every region interacts with all other regions, and the behavior of the weather in a given territory cannot be understood unless we know the properties of the air in large areas on all sides, and vertically upwards as well.

The projects for atmospheric investigations with satellites are designed to provide this overall view of the atmosphere and its properties, which constitutes an essential element of support for the future development of weather forecasting. In this manner our programs for atmospheric and meteorological research are intimately connected; and we can expect them, together, to produce major improvements in our understanding of the mechanisms that generate weather changes, and in the range and accuracy of weather forecasting.

It is in this way, through the union of the basic investigations into the laws of the natural world, and the projects for the prediction and control of natural events, that the space research program will have its major impact on the sciences.

NASA SPACE FLIGHT PROGRAMS

2. SATELLITES AND SPACE PROBES

by Edgar M. Cortright*

ABSTRACT

The United States has undertaken an intensive program to explore space with highly instrumented satellites and space probes. In addition to its basic contributions to science, this program will lay the groundwork for later manned exploration.

This paper presents a brief review of program objectives, successful spacecraft and their accomplishments, and spacecraft of the future.

INTRODUCTION

The exploration of space is an adventure story, one that has just begun to be written. History will record no single author—merely that in this infinitesimal segment of time and space man began to extend his domain beyond the confines of the Earth. Thus, in a sense, we are all authors.

The starry universe provides the incomparable setting for our story. It remains to outline the plot, the main characters, and some of the first significant episodes. In this talk I will attempt to provide this outline. My fondest hope is that I might stimulate more interest, understanding, and self-association on the part of the listener. The exploration of space is an experience to be enjoyed by every one of us.

WHAT ARE WE EXPLORING?

Space exploration, during its first decade, will concentrate on selected problem areas. These are depicted in figure 1. Our Sun is but one star in some hundred billion that compose our galaxy, known as the Milky Way. The relative position of the Sun is shown with the aid of a photograph of another galaxy on the left side of the figure. We are not now able to send spacecraft beyond the gravitational field of our Sun, but we can and do study other stars and galaxies with various types of telescopes, first from the ground and now from satellites.

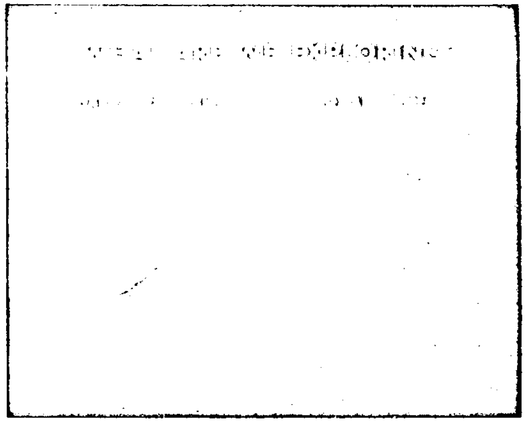


Figure 1

We can, however, explore the Earth's environment and selected portions of our solar system by sending instrumented spacecraft to these regions. As shown in the sketch on the right of figure 1, our nearest neighbors are the Moon, Venus, and Mars. During this decade we will concentrate on learning all we can about these celestial bodies and the interplanetary space in which they are immersed.

WE EXPLORE THE PLANET EARTH

The most convenient planet to study is the Earth itself. It is surprising that we know as little about the Earth as we do. By extending our knowledge of the Earth with scientific satellites, we are also gaining invaluable experience preparatory to exploring Mars and Venus.

*Assistant Director for Lunar and Planetary Programs, National Aeronautics and Space Administration.

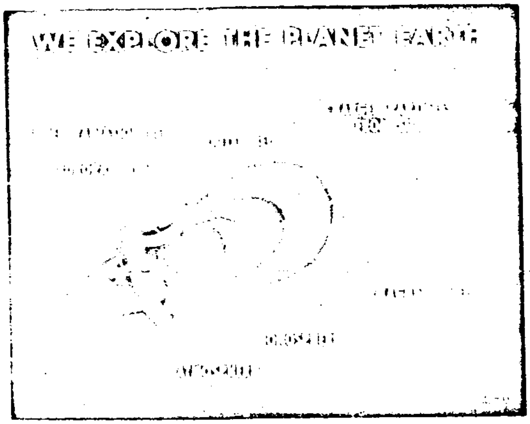


Figure 2

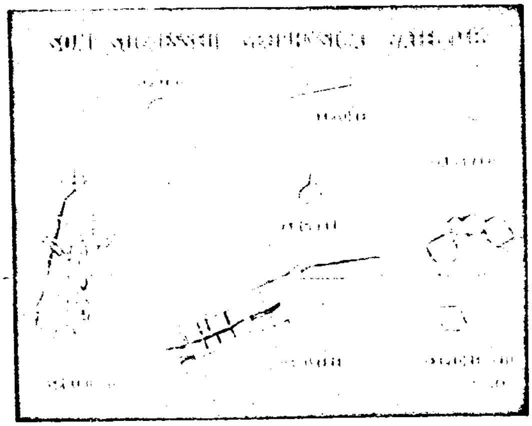


Figure 3

Figure 2 illustrates some of the phenomena we can study with the aid of satellites. These include the Earth's magnetic field, the belts of particles trapped in this field, and the influence of clouds of charged particles and radiations coming from the Sun. Among the practical contributions of such scientific studies will be a better understanding of the energy balance of the Earth and a better understanding of radiation hazards to future space travelers. Satellites are also extremely useful to the study of the ionosphere, the high-altitude layer of ions and electrons from which we reflect our worldwide radio signals. In addition, the upper regions of the Earth's atmosphere, where solar radiation produces mysterious effects, can be effectively studied with satellites.

The United States has successfully launched 41 satellites, and the Russians 11. Some of the more successful *scientific* satellites are shown in figure 3. Sputnik I was, of course, a dramatic first. Explorer I and Vanguard I were small satellites that made large contributions to our scientific knowledge. Vanguard III and Explorers VI to VIII are typical of the highly sophisticated satellites in the 50- to 100-pound class that we have launched with our first-generation launch vehicles, Vanguard and Juno II. Discoverer XIII, part of an advanced Air Force project, was the first satellite to return a payload from orbit. A later Discoverer flight returned important samples of radiation damage. Sputnik III was the heaviest scientific satellite and apparently the most successful Soviet effort in this field.

Some of the important scientific findings of these early satellites are indicated in figure 4. The radiation belts were among the first discoveries obtained with space vehicles. The characteristics of these belts were somewhat of a surprise. What was first thought to be one belt soon became two, and now there are indications of a third. The Earth's magnetic field, which holds the charged particles composing the radiation belts, has now been partially mapped to thousands of miles altitude. We now know that the Earth is not a slightly flattened sphere but is somewhat distorted in the shape of a pear, a significant result in terms of the structural strength of the Earth's crust

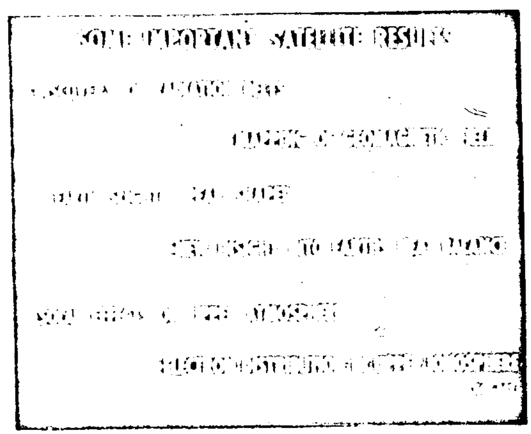


Figure 4

and in the science of orbit prediction. Measurements of the reflected and reradiated energy from the Earth, the atmosphere, and clouds have given us new insight into the heating and cooling processes that generate our weather. In addition, changes in the height of our atmosphere that are produced by solar influence have been detected from measurements of satellite drag. New information is being gathered on cosmic rays, and the top side of the ionosphere is now being carefully probed. As always, answers to old questions breed new ones, and such is the course of progress.

Our future approach to geophysical satellites will see the development of some large spacecraft that will replace many of the smaller ones now in use. Figure 5 illustrates some of these

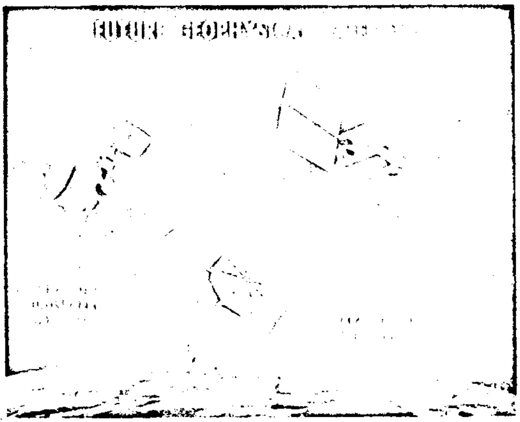


FIGURE 5

future spacecraft. One of these is the International Ionosphere Satellite, one of the spacecraft in NASA's program for international cooperation in space science. This satellite will make direct measurements of the properties of the ionosphere with a number of sensing instruments devised by scientists in the United Kingdom. The design and construction of the structure and data-transmission system for the satellite are the responsiblity of our own laboratories. Another spacecraft, not shown here, is being built by a Canadian group for other ionospheric studies. These projects will continue the program of direct ionospheric measurements from satellites that was initiated in Explorer VIII, launched in November 1960. The relatively inexpensive solid-propellant Scout vehicle will launch the satellite shown.

The satellite illustrated in the center of the figure carries many advanced instruments to study the particles and fields surrounding the Earth. It will be orbited with a Thor-Delta vehicle. The largest satellite is called OGO (Orbiting Geophysical Observatory) and will weight almost 1000 pounds. The Atlas-Agena launch vehicle will be used to put it into an orbit reaching 40,000 miles or more from Earth. OGO will carry many different experiments, and it is intended to be the mainstay of our geophysical satellite program for a number of years.

THE "NEW LOOK" IN ASTRONOMY

Since we cannot send our space probes to distant stars and galaxies, we must content ourselves with studying them from the vicinity of the Earth (fig. 6). Until the advent of the satellite, however, it has been necessary to conduct our astronomical observations through our obscuring atmosphere. As pointed out in the previous paper, the atmosphere filters out much of the radiation that can help us to draw new pictures of the heavens. These photographs of the Milky Way illustrate the effect of filtering action in changing our picture.

The United States is developing orbiting astronomical observatories such as those pictured in figure 7. The smallest of the trio, Explorer XI, has already been successfully launched. It will map the intensity of gamma radiation over the celestial sphere. This type of electromagnetic radiation is generated within stars and as a result of the interaction of cosmic rays with interstellar matter. Soon we will launch a solar observatory that will point constantly at the Sun and observe its ever-changing and sometimes stormy behavior. Late in 1963 we hope to orbit the highly advanced OAO (Orbiting Astronomical Observatory), which will weigh several thousand pounds and require the Atlas-Agena launch vehicle. This satellite, which constitutes a precision-stabilized platform, incorporates specialized optical systems for the study of the stars. It should mean a giant step forward in astronomy.

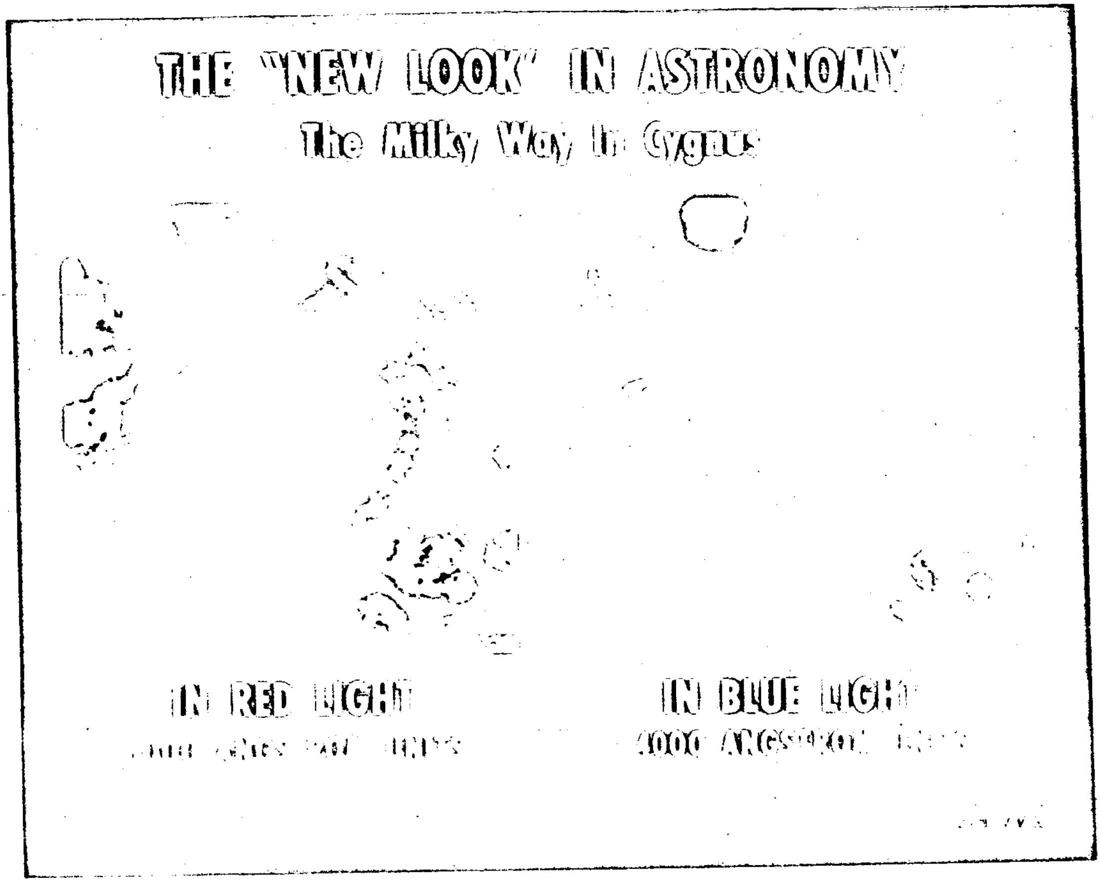


Figure 6

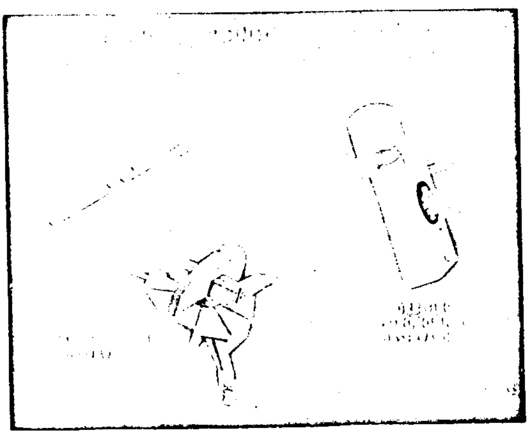


Figure 7

WE EXPLORE THE MOON

We can do more than look at our near neighbors in the solar system. We can first send instruments, and then man himself, and the Moon will be our first target (fig. 8).

A primary objective of lunar exploration is to pave the way for manned landings. This will involve a search for likely landing sites and a detailed survey of these sites for such hazards as rocks and boulders, cracks and fissures, steep slopes, and soft spots such as holes filled with dust. From a scientific point of view, we want to know much more about the Moon than the location of landing sites. We want to measure the chemical and mineralogical composition of its surface and subsurface, to determine its

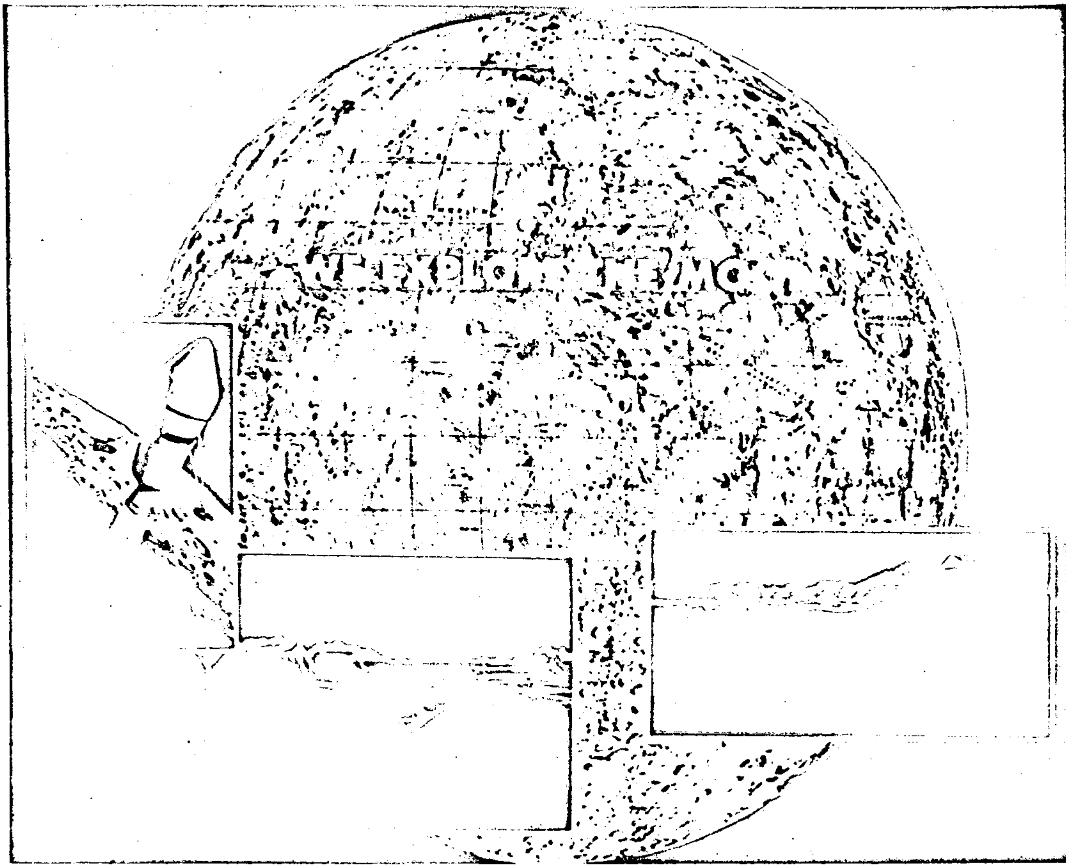


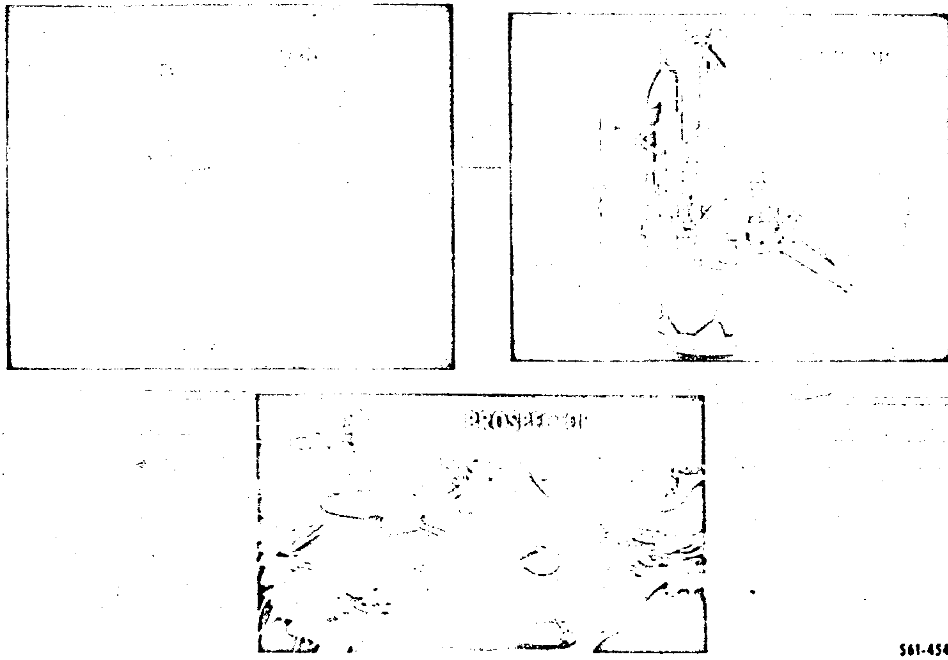
FIGURE 8

physical properties, and to deduce its interior construction. Knowledge such as this may unlock the secret of the formation of not only the Earth-Moon system, but of the entire solar system. In addition, it is conceivable that primordial life forms may lie preserved in the lunar dust that has been collected or generated over the estimated four billion years of the Moon's existence.

To accomplish these objectives requires a new family of spacecraft, which is illustrated in figure 9. The Ranger spacecraft is designed to land an instrumented capsule on the lunar surface and to view the surface with television and with a gamma-ray spectrometer during the descent phase of the flight. The spectrometer will provide clues to the nature of the lunar formation. The television will take photographs with up to 300 times the resolution of our best telescopic photography from Earth. Only the seismometer capsule will be slowed for the lunar landing. It should remain active for one to three months, listening for tremors that would provide data on the lunar seismic activity and clues as to the lunar construction. The Atlas-Agena launch vehicle is to be used for this project.

Project Surveyor, our first spacecraft capable of a true lunar soft landing, will constitute a tremendous advance in lunar exploration. This project should provide much of the information about the lunar surface and environment that is required to proceed with the development of more advanced unmanned and manned landing spacecraft. In addition, much of the guidance, control, communications, power, and landing technology required for these later missions will be developed in the

FUTURE LUNAR SPACECRAFT



561-454

FIGURE 9

course of the Surveyor project. Modification of the Surveyor may give us a capability of photographic mapping from orbit. Launched with the Centaur vehicle and weighing approximately 2500 pounds at injection, the Surveyor will land about 750 pounds on the lunar surface. Of this, some 250 pounds will be scientific instrumentation. As now planned, several television cameras with variable magnification will examine the surrounding surface features in great detail. A variety of spectrometers will analyze the composition of surface and subsurface samples collected with the aid of drills. Physical properties of the samples will also be determined, and the samples will be examined for the presence of organic molecules.

The extremely tenuous lunar atmosphere will be analyzed, and the radiations that shower the lunar surface will be measured with a variety of detection devices. Some of the properties of the Moon as a planetary body will be determined from seismometer and gravimeter measurements.

Beyond Project Surveyor, we will probably move directly to an automated spacecraft capable of providing direct support to manned operations on the Moon. Project Prospector will be capable of landing thousands of pounds of useful payload at a predetermined location on the lunar surface.

The Prospector landing spacecraft or "truck" will be versatile enough to land many types of cargo. Before the landing of man we will be able to establish a small depot of supplies and equipment, possibly including a "jeep" for surface transportation and small rockets to return selected surface samples to

Earth. An instrumented version of this mobile vehicle could provide a detailed site survey prior to manned landing, as suggested in the figure. We could also provide man with a small radiation shelter to protect him from solar storms. During manned operations, the Prospector could land emergency supplies and equipment. In these and other ways the unmanned lunar program constitutes a portion of the logical progression toward manned exploration.

WE EXPLORE VENUS AND MARS

Our first planetary missions will be directed toward our near neighbors, Venus and Mars. Figure 10 highlights some of the mysteries

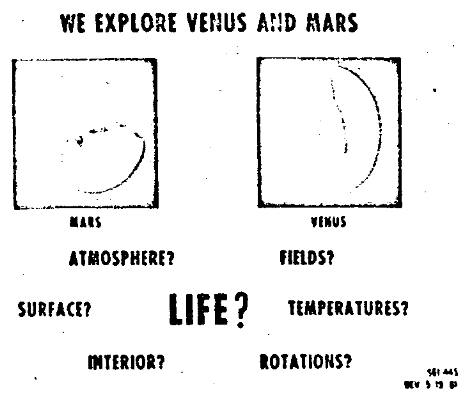


FIGURE 10

of these planets. Astronomers have been able to see a number of interesting markings on Mars. These include the polar caps, dark markings termed "maria," bright areas called "deserts," linear markings known as "canals," and circular dark markings called "oases." In addition, various color clouds and a blue haze in the atmosphere have been observed. Venus is more shy than Mars. Although she peeks out from behind her shadow as she passes close to the Earth, she remains cloaked in a heavy blanket of clouds. We never see much more than is shown in the picture. Although we study these planets from Earth with many types of instruments, we can answer only a few questions about their atmosphere, surface, interior, temperature, and motion. The most intriguing of all speculations about the planets concerns the presence or absence of life. To answer these questions it will be necessary to send instrumented spacecraft to these planets. Some day, man will follow.

Opportunities to launch spacecraft to Venus and Mars occur every 18 and 24 months, respectively. As yet there have been no successful planetary missions, but in 1962 we will attempt, in Project Mariner, to fly a spacecraft past Venus. Since the Soviet Union has already made several such attempts, we must assume that they will try again. Our future planetary spacecraft are shown in figure 11. The

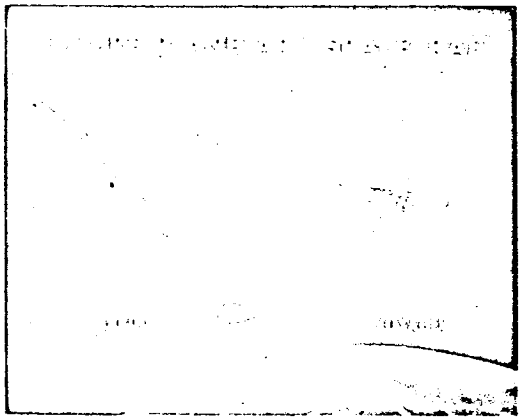


FIGURE 11

Mariner spacecraft will be launched with a Centaur rocket. It will carry a comprehensive array of radiation and field measuring instruments to provide data on interplanetary phenomena en route. At Venus, however, the prime experiments will be a radiometer to scan the planet for temperature distribution, an ultraviolet spectrometer to examine the atmospheric constituents, and a magnetometer to measure possible planetary magnetic fields. In addition, the radiation detectors may provide important information about the planet if the spacecraft passes close enough to detect trapped particles.

The 1964 versions of the Mariner may be capable of injecting a small capsule into the planetary atmospheres of Mars and Venus as the spacecraft flies by. However, the Saturn-launched Voyager is required for more than a cursory observation of these planets. An artist's conception of the Voyager spacecraft is shown in figure 11. This spacecraft, weighing about 2400 pounds, would be designed to orbit the target planet and to inject an instrumented capsule capable of surviving atmospheric entry and descent to the ground. Thus, the orbiting spacecraft would observe the planet and its atmosphere from an altitude of several hundred miles, while the landing capsule would make detailed measurements during its descent and on the ground. Data from the capsule, including TV pictures, would probably be relayed to Earth via the mother spacecraft. Numerous scientific and technological developments are required to accomplish this difficult but fascinating and distinctly realistic mission, which may well include, among its rewards, the discovery of extraterrestrial life.

WE EXPLORE INTERPLANETARY SPACE

The so-called "void" of interplanetary space is filled with many types of radiations and with magnetic fields that generate interesting and important phenomena (fig. 12). Scientists are

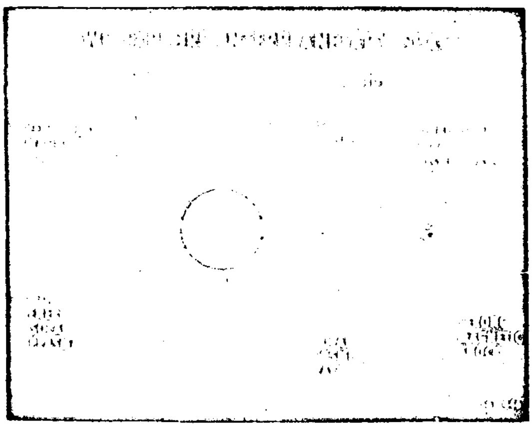


FIGURE 12

beginning to draw qualitative analogies between the material in interplanetary space and the Earth's atmosphere. Both are restless, ever-shifting and changing, and subject to storms of various types that can be dangerous and that must be better understood.

Some of the important findings of interplanetary probes to date are illustrated in figure 12. During times of relative solar quiet, a weak magnetic field of solar or galactic origin has been measured in the region of interplanetary space between the orbits of Venus and Earth. Low-energy solar plasma is also believed to have been detected. During solar storms, the situation changes radically. A magnetic shock wave has been found to precede a flood of high-energy plasma ejected from the Sun. Solar cosmic rays have also been observed during such periods. These radiations are sufficiently intense to endanger the life of an unprotected space traveler. Strong magnetic fields have been observed as well. Following storms of this type there is often a noticeable decrease in the intensity of galactic cosmic rays striking the Earth. Measurements from Pioneer V have shown this phenomenon also to occur millions of miles from the Earth. Thus, it has been suggested that the magnetic fields sweep many cosmic rays from the solar system.

The most successful interplanetary probes are shown in figure 13. The Soviet Mechta, the first, relayed data to the Earth from over 200,000 miles. Pioneer V, the dramatic U.S. "paddlewheel" spacecraft, remained in contact with the Earth for over 22 million miles. The most recent of the trio, Explorer X, was designed to make critical magnetic-field and plasma measurements that will answer certain questions posed by the earlier flights.

The flight of Pioneer V is illustrated in figure 14. On March 11, 1960, Pioneer V was launched in a direction opposite to that of the Earth's travel about the Sun. This was the first spacecraft to be launched on a trajectory carrying it inward toward the Sun. Communications were maintained with Pioneer V until

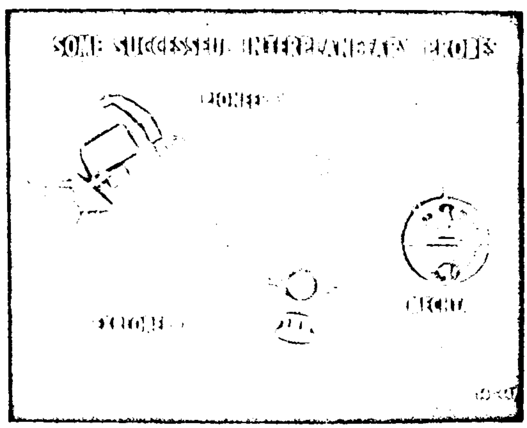


FIGURE 13

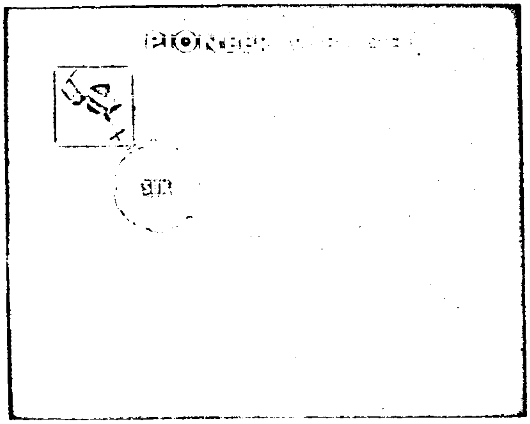


FIGURE 14

June 26, 1960, at which time it was 22½ million miles from the Earth. At this point the spacecraft had travelled one-fourth of the distance around the Sun and had moved about eight million miles closer to the Sun. Failure of the power supply caused a somewhat premature end to communications, but not before highly useful scientific results were obtained. The March 31 solar flare was the cause of some of the most interesting phenomena observed during this historic flight.

WHO ARE THE SCIENTISTS?

The NASA is attempting to marshal the best scientific effort in this country to conduct the complex experiments just described. In addition, foreign scientists are being invited to participate in a number of areas. Over 100 scientists from 35 universities are engaged in work on the many experiments in our space-flight program. This number is increasing steadily. Other experiments are conducted by scientists working in various Government laboratories.

NEW CHALLENGES FOR INDUSTRY

The great majority of NASA funds are spent with U.S. industry. The successful exploration of space rests heavily on this group. Many difficult technological problems must be solved. New standards of quality and reliability must be achieved. New approaches to low-volume manufacture of complex equipment are required. Fortunately, years of experience with the most modern of aircraft and missiles have set the stage for this new era.

CONCLUDING REMARKS

The goals described in this program of space exploration are difficult to attain. We know beforehand that success will not be achieved without our encountering failures along the way. However, by applying the skills and intellect of the nation in this most difficult of technological areas, we can be confident not only of succeeding in space exploration, but of sharing the many unforeseen benefits that always accrue from such national endeavors. What is more, we can each enjoy the experience.

NASA SPACE FLIGHT PROGRAMS

3. WEATHER AND COMMUNICATION SATELLITES

by DEMARQUIS D. WYATT*

A new dimension was added to the world's meteorological forecasting techniques when, on April 1, 1960, the TIROS I satellite was launched by the United States. For 1302 orbits around the Earth in a period of 78 days, the spacecraft transmitted a stream of pictures of the covering clouds—pictures taken from above the clouds and embracing areas up to 500,000 square miles each. In all, almost 23,000 pictures were taken by TIROS I, and about 60 percent of these were of meteorological value.

On November 23, 1960, TIROS II was launched into orbit. It is still transmitting useful data, not only in the form of cloud photographs, but also infrared measurements of the Earth's radiation balance.

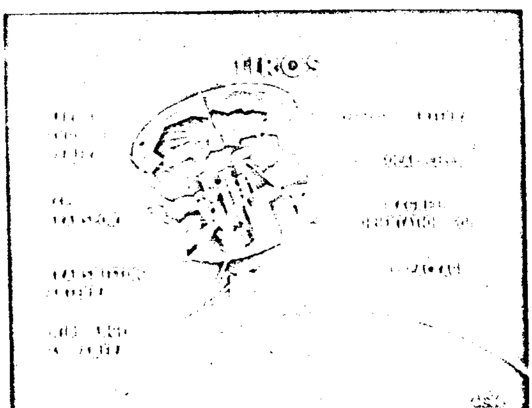


FIGURE 1

Figure 1 shows the hat-box shaped TIROS satellites. About 19 inches high and 42 inches across, the two were nearly identical. Both were launched into nearly circular orbits a little more than 400 miles above the Earth. TIROS I weighed 270 pounds. It contained two television-type cameras, picture-storage tapes and readout equipment, and the electronic equipment necessary to transmit pictures on command to ground receiving stations at Fort Monmouth, New Jersey, and Kaena Point, Hawaii.

One camera had a wide-angle lens and took a picture about 700 miles on a side. The other, a narrow-angle camera, gave greater resolution; but the pictures only covered an area of about 70 by 70 miles. The pictures were not continuous, as we generally conceive of TV, but were essentially snapshots. On ground command, or by a preset timer, the camera shutters would expose the vidicon tube momentarily. The resultant picture was stored on the tube face and then read off by a scanner. This scanning signal could be transmitted directly to Earth or stored on a tape for readout upon passage over a receiving ground station, as required. The picture resolution, or detail, was limited by the number of lines on the scanning circuit. The pictures from the narrow-angle camera would permit identification of objects larger than 700 feet across. The wide-angle pictures could not differentiate objects smaller than about 1.4 miles.

In addition to the cameras and associated electronics, TIROS II has infrared radiation equipment to measure the atmospheric heat budget, or radiation balance, and a magnetic orientation coil to provide a measure of control of the direction in which the satellite points.

With the receipt of the very first pictures from TIROS I on the first orbit, it became apparent that the satellite system was photographing clouds, cloud formations, and pat-

*Director of Programs, National Aeronautics and Space Administration.

SOUTHERN HEMISPHERE STORMS

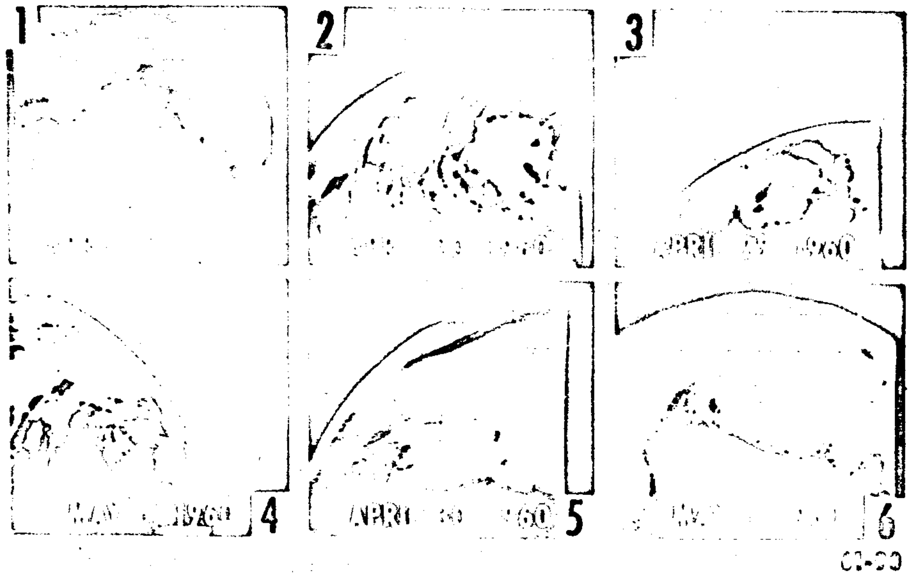


FIGURE 2

terns. Meteorological research teams at the U.S. Weather Bureau, the Air Force Cambridge Research Center, the Naval Weather Research Facility, and other institutions immediately attacked the problem of interpreting the TIROS pictures in terms of weather content. Their findings confirmed previous suggestions based on limited photographs from high-altitude rockets that Mother Nature was drawing her own weather map by means of clouds.

Figure 2 shows six storm pictures taken in the Southern Hemisphere. In the upper left is a typhoon just to the north of New Zealand. Pictures 2 and 3 show later stages of the same system in the Indian Ocean off Madagascar. The lower three pictures are typical of other storms that move endlessly eastward in the data-sparse roaring 40's belt to the north of the Antarctic continent.

By matching together overlapping photographs such as these, it is possible to construct mosaics covering very large areas of the Earth's surface. The top of figure 3 shows a photo-mosaic extending almost 5000 miles from the mid-Pacific to the central United States. Below, these cloud pictures are translated to map coordinates and are superimposed on a conventional meteorological analysis. The cloud photographs at once confirm and amplify the ground-determined weather analysis.

Having determined that TIROS could be used to provide unique and detailed data about weather processes, it next became important to determine whether forecasting information could be extracted with sufficient speed to meet

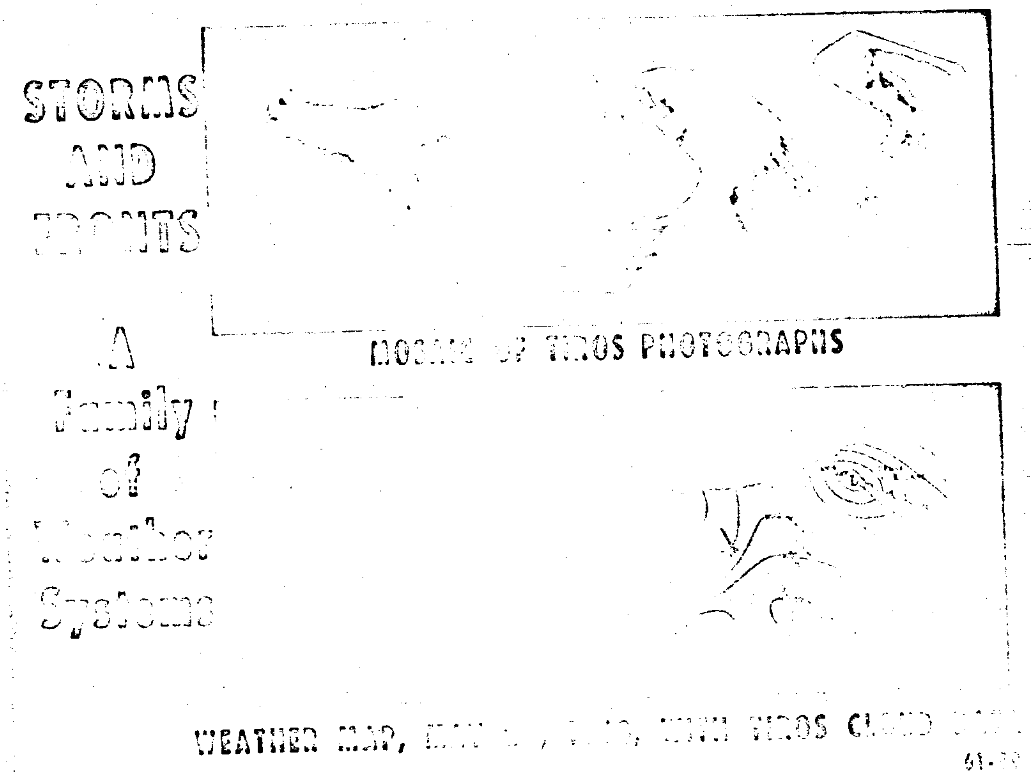


Figure 3

needs. After all, there is nothing less valuable than today's forecast of yesterday's storm.

Meteorological teams at the data-acquisition stations analyzed the incoming data on the spot. Within 60 hours after TIROS I was launched, pictures less than 6 hours old were being interpreted and the resultant analyses forwarded via facsimile transmission to the National Meteorological Center of the U.S. Weather Bureau at Suitland, Maryland. Figure 4 is a copy of one of those transmissions. It covers part of the cloud region on the previous chart. (Nephanalysis is a meteorologist's way of saying "cloud analysis.") The region covered extends from the tip of the Aleutian Islands to hundreds of miles inland on the U.S.-Canadian border. Transmissions such as these are being incorporated into regular analyses of the U.S. Weather Bureau. Copies are also relayed to our air and naval services here and overseas.

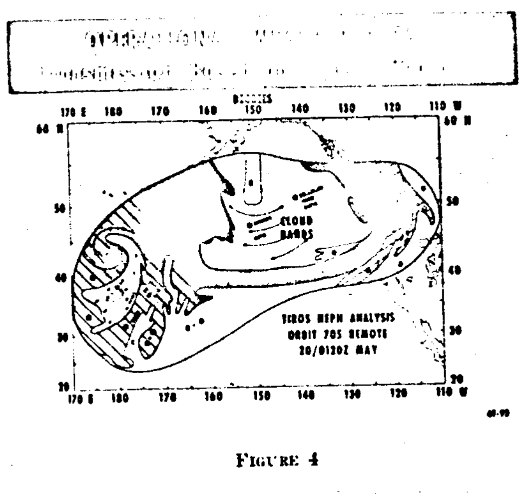


Figure 4

The infrared data from TIROS II are more fundamental in character and cannot yet be utilized in routine analyses. The data must be reduced and plotted on maps by a rather laborious process before they can be interpreted. Figure 5 shows the type of measurements taken

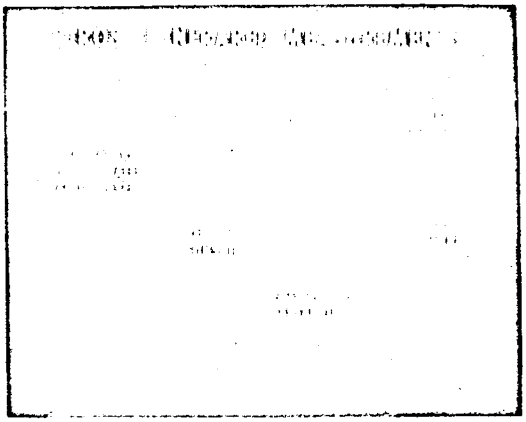


FIGURE 5

by TIROS II. They include:

(1) The temperature at the top of the water-vapor layer

(2) Surface temperatures or cloud-top temperatures

(3) The amount of reflected radiation

(4) The amount of emitted radiation

(5) Low-resolution cloud pictures.

A typical IR "map" is shown in figure 6. It covers the southwest Pacific region from southern Australia and Tasmania past New Zealand. The numbers show temperatures on the absolute

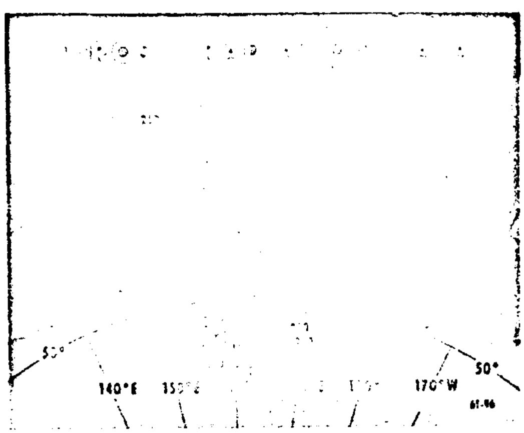


FIGURE 6

Centigrade scale. Comparisons with other meteorological data have indicated that the areas of low temperatures are related to frontal-cloud bands, and the high temperatures with clear areas.

Our results from the TIROS satellites have indeed been impressive. The response from the using weather agencies has been so favorable that every effort will be exerted to keep at least one working TIROS aloft at all times in the near future. TIROS has several distinct limitations, however, that have led NASA and the weather agencies of the United States to proceed with the earliest possible development of a more advanced meteorological satellite.

Figure 7 illustrates the principal TIROS limitations on the left. It is a spin-stabilized

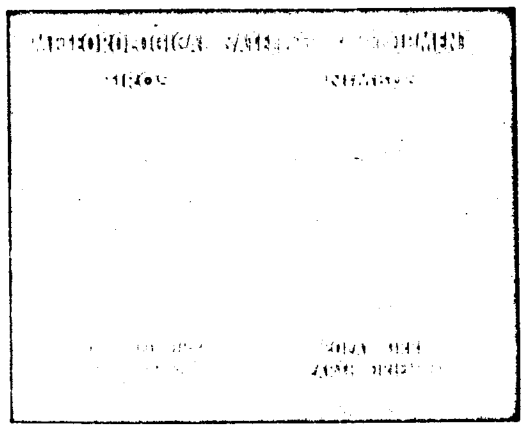


FIGURE 7

spacecraft that is space-oriented; that is, it tends to point at a fixed point in space as it orbits the Earth. As a consequence, the cameras only point at the Earth for useful photography during about 25 percent of the orbit. Both TIROS I and II were launched on inclined orbits, so that the coverage of the Earth's surface was limited to the area between 50° N and 50° S latitude.

Both of these limitations should be overcome when the NIMBUS family of meteorological satellites is launched, starting in 1962. These will be launched into polar orbits so that all areas of the Earth will be viewed twice a day, once about local noon and once about local midnight. NIMBUS will have an orbital period of about 108 minutes. A stabilization system is being incorporated that will cause the spacecraft to pitch end-over-end at the same rate, once every 108 minutes, so that the camera end will always point at the Earth. This creates what is known as an Earth-stabilized spacecraft.

A better view of what NIMBUS will look like is shown in figure 8. The solar platforms,

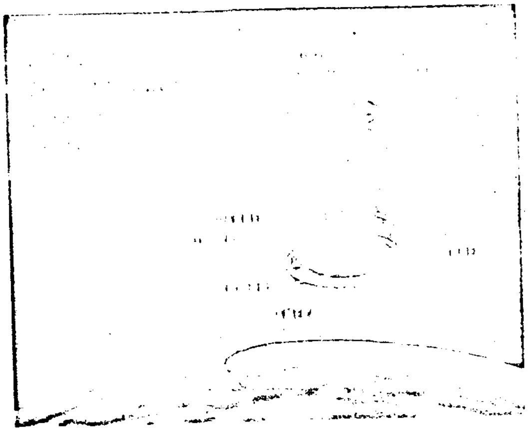


FIGURE 8

or paddles, will be covered with solar cells to provide on-board power. These paddles will be controlled so that they always face the Sun as the spacecraft itself topples end-over-end. Thus, the solar platforms will rotate relative to the main spacecraft body at about one revolution every 2 hours.

The section to which the solar paddles are affixed will contain the controls for keeping the spacecraft axis, and hence the cameras, always facing the Earth. At the bottom of the connecting struts is a section that will contain the sensory devices and the spacecraft readout and data-transmission electronics. In the first two NIMBUS satellites, the sensors will include three wide-angle TV cameras that will have overlapping fields of view. These will provide a cloud resolution between the present limits of the wide- and narrow-angle cameras of TIROS. In addition, these spacecraft will contain high- and low-resolution infrared scanners for making night-time cloud-cover measurements, and an experiment to measure the value of the solar constant, or rate of radiant heat coming from the Sun.

This instrument section is being designed on a modular, or standardized compartment, basis so that, in later NIMBUS spacecraft, the early sensors can be replaced with improved or new types of equipment without having to redesign the whole satellite. Advanced versions of NIMBUS are expected to carry such additional devices as electrostatic-tape cameras for improved cloud photography, a radar set to provide data on areas of precipitation, an instrument to provide data on the temperature structure of the atmosphere, and an instrument to identify thunderstorm areas.

NIMBUS launchings will occur at about 6-month intervals during the period of development of the system. All of the four to six spacecraft in this research and development phase can and will be used to provide data for international operational purposes. These data will be read out during satellite passes over or near a ground station at Fairbanks, Alaska, and will be transmitted in real time (meaning instantaneously) to the National Meteorological Center. There they will be analyzed and the results distributed to civilian and military weather stations.

These research and development NIMBUS flights will be augmented by other NIMBUS launchings directed by the Weather Bureau to ensure a steady flow of weather data. During the period of spacecraft development, a simultaneous development of ground data-handling and analysis methods will be under way. When these development efforts are completed, the United States will have an operational satellite weather system.

Our thinking in weather satellites has not stopped at the NIMBUS system. While the entire Earth will fall under its vision, any given region will only be observed at intervals of several hours. The meteorologist is interested in the capability of continuous observation of developing storms. Figure 9 shows an AEROS satellite that may, in the future, provide this capability. This would be launched into an altitude where its period of orbit around the Earth would correspond to the rotational period of the Earth—24 hours. Thus, the satellites would appear to remain stationary and be overhead at all times. This orbit would occur

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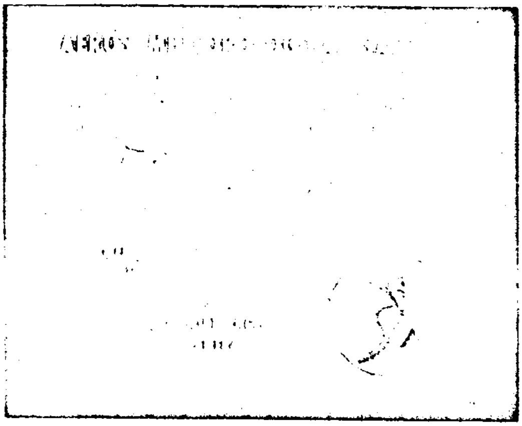

FIGURE 9

over the equator, so that the field of view would not include the extreme latitudes near the poles.

Such a satellite is conceived as carrying a variable-focus camera system so that, on command, the field of view could be changed from a broad-scale picture of the Earth to a view of a localized spot determined to be of meteorological interest. We expect to initiate development of such a camera during the coming fiscal year.

At this time, the prospects for improvement of our weather forecasting through the use of meteorological satellites appear bright. The advantages to be accrued from such a system will not be limited to the United States, for weather is an international problem. Argentina, Australia, Belgium, Czechoslavakia, Denmark, Italy, Japan, The Netherlands, Switzerland, and West Germany have been participating in the TIROS II program by making special ground measurements to correlate with the satellite observations as it passes over their countries. More countries will be invited and are expected to join in the later programs. Here is one product of the Space Age that may serve to bring the international community into closer cooperation and harmony.

Another space development that should be equally important in unifying the peoples of the Earth is the satellite communication system. Within the past 50 years our Earthbound methods of long-distance communication using telephone and telegraph wires and cables have been extended via radio so that almost any point on the Earth can be reached. The radio systems that we use, however, are not entirely suitable for the rapidly developing world civilization. The fact that really long-distance radio transmission must depend on reflection of the signals from the ionospheric layers around the Earth has made it necessary for us to restrict our intercontinental communication systems to very narrow regions in the radio spectrum. In general, this has resulted in a relatively low system capacity: We cannot transmit many messages at one time and we cannot transmit such information as television, which requires a very wide band in the spectrum. In addition to this capacity limitation, the reliability of overseas transmission is less than optimum because of the variable nature of our reflector, the ionosphere. The layers shift or even disappear as a function of solar activity, so that we are subject to undesirable radio blackouts that disrupt communications.

It now appears feasible and practicable to consider world-wide communications using Earth satellites to artificially reflect or retransmit very high-frequency radio signals. This should give us the capacity for transoceanic television or many simultaneous telephone and telegraph messages, and at the same time allow us to operate without transient garbling or interruption due to ionospheric disturbances.

For the past 2 years NASA has been aggressively developing the technology required for several different kinds of satellite communication systems. Last August 12, the Echo sphere was launched. The following motion picture will review some of the steps leading up to that launching.

Film Narrative

"Early in the program, the Langley Research Center was given the satellite development responsibility.

"Many industrial concerns contributed. The General Mills Corporation developed cutting processes for the DuPont Mylar from which the satellite is fabricated, and the J. T. Schjeldahl Corporation developed a process for joining the pieces together.

"Every inch of the structure had to be inspected. For this purpose, the 100-foot-diameter sphere was inflated in a huge hangar. For launching, this huge sphere had to be folded into a 26-inch-diameter container. A sublimating powder was placed inside the satellite prior to folding. It is this material that would evaporate in space and inflate the 100-foot sphere.

"The satellite package design and ejection and inflation techniques were tested in 60-foot vacuum chambers at Langley Research Center, but the final test had to be in the space environment itself. The satellite package was tested in vertical test flights from Wallops Island.

"Following the first completely successful vertical test flight on April 1, 1960, a beacon transmitter was added to the satellite to assist in tracking. The beacon was developed by RCA and consisted of a transmitter less than 1 inch square powered by tiny batteries and solar cells.

"Concurrently with the satellite development, a new powerful transmitter was being developed at NASA's Jet Propulsion Laboratory and at Bell Telephone Laboratory, Holmdel, New Jersey, and a new type of receiving system got under way. The new horn type of antenna contributed very little noise to the systems, making possible the reception of very weak signals with newly developed maser amplifiers.

"These equipments, when completed, were checked out and exercised using the Moon as a reflector of radio signals. New methods of antenna pointing and prediction of antenna pointing instructions had to be generated for the Echo experiment.

"The booster vehicle which was to launch Echo was the newly developed Delta three-stage rocket. The first attempt occurred on May 13, 1960, and a loss of attitude control in the second stage caused failure of the mission. On August 12, 1960, the second flight of the Delta was completely successful."

Figure 10 shows some of the significant communications accomplishments using the Echo satellite. On the first orbit, within 2 hours of launching, a previously recorded message by President Eisenhower was transmitted from Goldstone, California, to Holmdel, New Jersey, using the facilities you saw in the film. This was particularly significant because at that time a solar disturbance had blacked out conventional high-frequency long-distance radio communications.

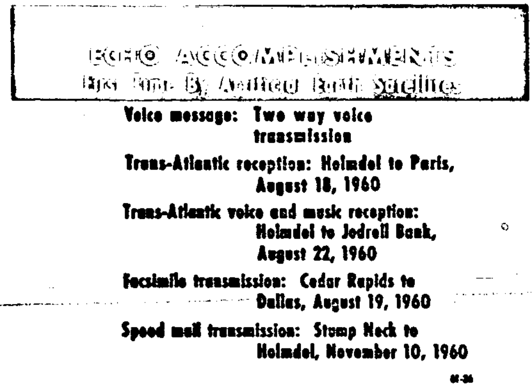

FIGURE 10

In rapid succession, many Echo "firsts" were recorded. A two-way telephone conversation was held from JPL to the Bell Telephone Laboratory, and a signal was relayed to a station near Paris, France. On August 22, voice and music were successfully transmitted from Holmdel, New Jersey, to Jodrell Bank, England. On August 19, independent experimenters, The Collins Radio Company at Cedar Rapids, Iowa, and their affiliate, the Alpha Corporation at Richardson, Texas, transmitted the first facsimile picture via Echo. On November 10, NASA performed an experiment with the Post Office Department on the possible uses of satellies for Speed Mail.

Figure 11 shows a photograph after facsimile transmission via the satellite. This picture

FIGURE 11

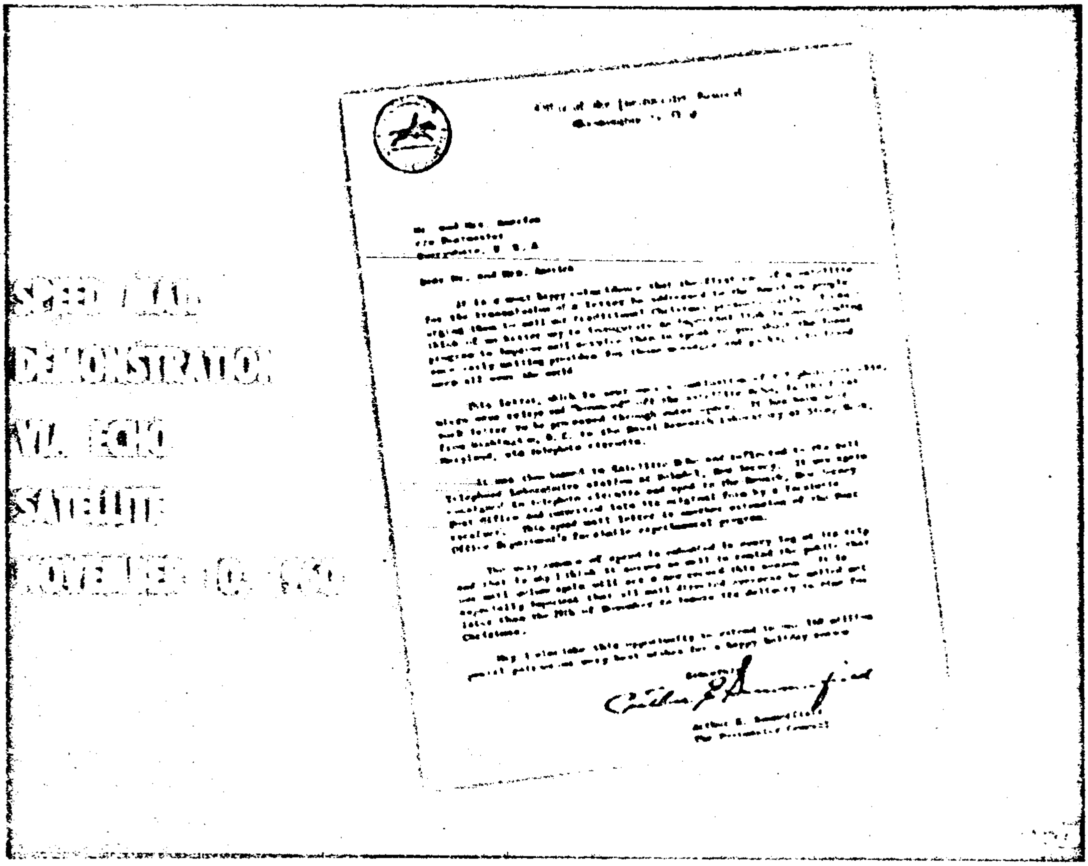

FIGURE 12

was taken at Holmdel, New Jersey, with the BTL ham antenna in the background.

Figure 12 shows the letter sent in the Speed-Mail demonstration.

The principal results from Echo, which is still visible, are shown in figure 13:

(1) We found that a passive communication system is feasible.

(2) The radio propogations theories were confirmed. This means we can predict communications performance at other altitudes and other frequencies than those used for Echo.

(3) We can reasonably predict the orbital behavior of the inflated spheres. Echo was initially launched to a nearly circular altitude with a perigee of 950 miles. The radiation pressure from the Sun pushed the sphere relative to the Earth so that a minimum altitude of about 600 miles was reached the first of this year. As a result of the Earth's motion around

RESULTS OF ECHO

- **Feasibility of Passive Systems Demonstrated**
- **Confirmed Radio Propagation Theory**
- **Confirmed Orbital Behavior Theory**
- **Proved usefulness of Large, Erectable, Long-Lived Space Structures**

61-30

FIGURE 13

the Sun, the sphere is now being pushed back away from the Earth. This motion has proved to be predictable.

(4) Since Echo did not collapse after the loss of its pressurizing material, the thin, 0.0005-inch-thick plastic-film structure has provided us with the confidence that large, erectable structures can be made to retain their shapes for long periods of time.

As a follow-on to Echo, we are proceeding with the development shown in figure 14. This

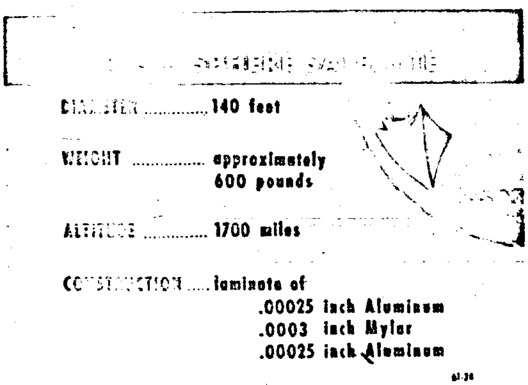

FIGURE 14

new sphere will be made of a laminate of two layers of aluminum foil ¼-thousandth of an inch thick on either side of a ⅓-thousandth-inch-thick-sheet of Mylar plastic. It is calculated that this structure will be about 20 times more resistant to buckling than the Echo sphere, which was made of ½-thousandth Mylar with a vapor-deposited aluminum inner and outer coat. The new sphere will be 140 feet in diameter, where Echo was 100 feet. Because of its higher flight altitude (1700 miles as compared with 1000 for Echo) the new sphere should have about the same brightness for the observer from the ground.

If a satellite communication system is to offer full-time capabilities, it will be necessary to have a number in orbit simultaneously so that one will always be visible. Part of the new reflecting-sphere project, to be known as Project Rebound, will involve the ejection of three spheres from a single launching vehicle at a prescribed spacing. These tests will be preceded by a launching of only one of the new spheres so that we can verify its predicted separation and inflation characteristics and determine its useful life in the orbital environment.

In terms of overall communications systems, passive reflecting spheres of the Echo type have certain disadvantages that can be overcome by other types of satellites. The principal disadvantage is the very large ground-transmitter power required, since the sphere simply reflects the signal and adds no boost to it. This deficiency can be overcome by making the satellite a much smaller active electronic package such as that shown in figure 15.

This active repeater satellite is a combined receiving and transmitting station powered by the Sun through solar-cell conversion of the Sun's energy to electrical energy. The signal received from the Earth is instantaneously rebroadcast after a power boost from the transmitter. This makes the satellite a relay station; and we are, in fact, calling our first active communication satellites Project Relay. These are to be built by the Radio Corporation of America, who were recently selected after a design competition.

In addition to providing demonstrations of intercontinental communications, including

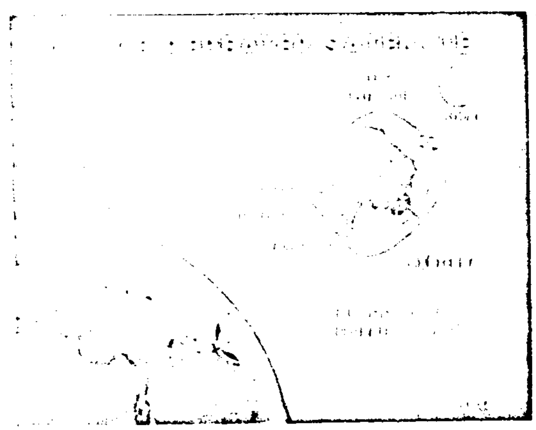

FIGURE 15

trans-Atlantic television, Project Relay will be used to explore the many technological problems of active electronic systems that must operate for long periods of time in the great radiation belts around the Earth shown in figure 16.

We know from our scientific space flights that the radiation in these belts can affect the

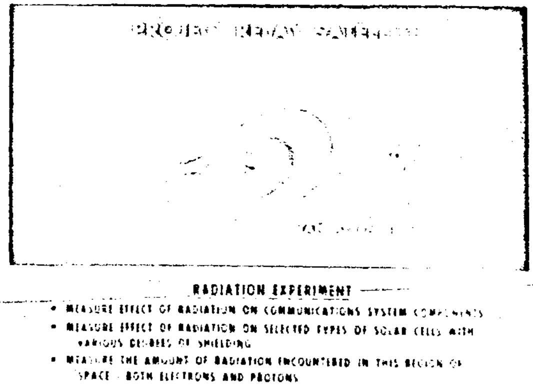

FIGURE 16

life of solid-state electronic components such as solar cells, transistors, and diodes. In our Project Relay satellites, we shall therefore measure the life history of the communication-system components, not only by observing overall performance but by measuring the individual characteristics of a number of the critical components. We shall also incorporate several different solar-cell arrays with different shieldings, and we will measure the comparative long-time performance of each.

In order that we can acquire the kind of data that will let the communications industry make early, meaningful design decisions in later satellities, we will make continuous measurements of the amount and kind of radiation encountered by the Relay satellites. Thus, these satellites will measure both the cause and effect.

An active satellite communication system meeting the necessary standards of reliability and durability (or long life) that we have come to expect as a matter of course from our communications industry must await the kind of research and development results that we will obtain from Project Relay. Nonetheless, the potential to the world of such a system is so great that NASA is going to undertake, in concert with the communications industry, the early implementation of an interim or transitional system until the state of the art is sufficiently developed for full commercial systems. Funds for this transitional system have been requested from the Congress by President Kennedy. We will expend these funds in support of broad industry efforts that will bring the maximum skill and ingenuity of the United States to the early solution of the problem.

In the Aeronautical and Space Act of 1958, which created NASA, the Congress declared it the intention of the United States to seek the peaceful utilization of space. The projects I have discussed in meteorology and communications are an important part of the national program to achieve that goal for all mankind.

NASA SPACE FLIGHT PROGRAMS

4. MANNED SPACE FLIGHT

by GEORGE M. LOW*

INTRODUCTION

It is my purpose to discuss NASA's program for manned space flight—a program that will allow man to participate directly in the exploration of space.

The first step in this program is Project Mercury. This Project, as you know, is designed to put a manned satellite into an orbit more than 100 miles above the Earth's surface, let it circle the Earth three times, and then bring it back safely.

From Project Mercury we expect to learn much about how man will react to space flight, what his capabilities may be, and what should be provided in future manned spacecraft to allow man to function usefully. Such knowledge is vital before man can participate in other, more difficult, space missions. But the determination of man's capabilities is only one of the objectives of Project Mercury. Of equal importance is the technical knowledge that is being gained during the design, construction, and operation of our first vehicle specifically engineered for manned space flight.

The first major milestone in Project Mercury was successfully accomplished earlier this month. On May 5, 1961, Alan Shepard made a suborbital manned space flight in a Mercury spacecraft launched by a Redstone booster. In this flight he reached a velocity of 5100 miles an hour, an altitude of over 100 miles, and travelled to a distance of 300 miles from Cape Canaveral. Later on in my presentation I will give a more detailed description of Shepard's flight, and will present some of the important results of this flight.

Much work remains to be done, however, before the final objective of Project Mercury, manned orbital flight, is achieved. Unmanned orbital flights using the Atlas launch vehicle are scheduled for this summer. If all goes well, the first manned orbital flight will be made before the end of 1961.

But project Mercury is only a beginning, a first step in our long-range program for manned exploration of space. The next step in this program has been designated Project Apollo.

PROJECT APOLLO

Project Apollo will lead ultimately to a manned landing on the Moon. Such a venture will require technological advancements far in excess of those needed for Project Mercury: It will require the development of an advanced manned spacecraft that can withstand the high loads of the launching, that can be guided and steered toward the Moon, that can land gently on the Moon, and then be launched from the Moon and guided back toward the safe reentry and recovery on Earth. It will require the development of a launch vehicle that is 30 to 50 times as powerful as the Atlas booster, and of propulsion systems for the lunar landing and takeoff. And, above all, it will require a highly competent team of engineers and scientists who can carry out such a complex project.

THREE APOLLO MISSIONS

Because a manned lunar landing will represent a major advancement in the state of the art, the Apollo project will involve several intermediate steps, as shown in figure 1. The Apollo spacecraft will first be flown in Earth orbit, where the many spacecraft components and systems will be tested and evaluated in a space environment. The Earth-orbital flights will also be used for space-crew training and

*Chief, Manned Space Flight, National Aeronautics and Space Administration.

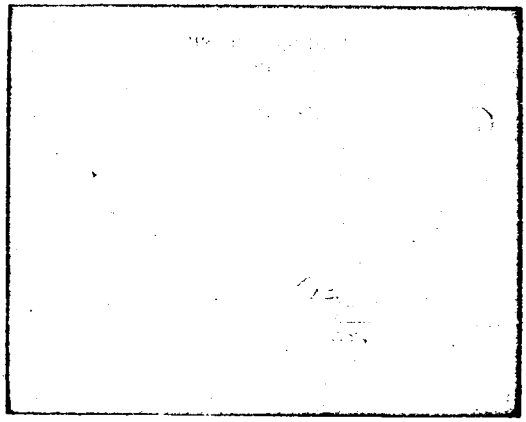

FIGURE 1

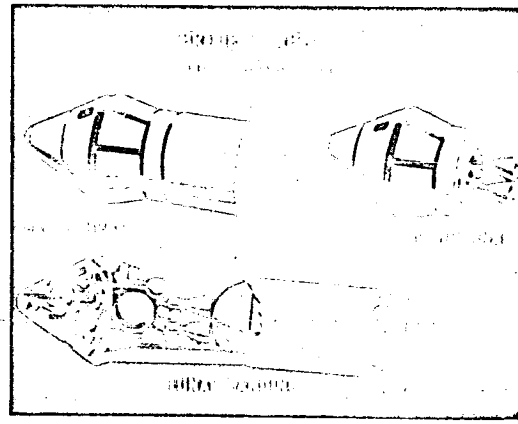

FIGURE 2

for the development of operational techniques. In conjunction with these qualification flights, the spacecraft can be used, in Earth orbit, as a laboratory for scientific measurements or technological developments in space.

Following the Earth-orbital flights, the craft will be flown to greater and greater distances from the Earth. Another major step in the program, therefore, will be manned circumlunar flight. In circumlunar flight the crew will perform many of the guidance and control tasks that will later on be needed in the lunar-landing mission. The events encountered during return to Earth, during the high-speed reentry, and during the Earth-landing phase will also be duplicated in the manned circumlunar flights.

These preliminary flights in Earth orbit, and around the Moon, will logically lead to the final Apollo objective—manned landing on the Moon.

APOLLO CONFIGURATIONS

Our designs for the Apollo spacecraft have not yet progressed to the point where I can tell you exactly what this craft will look like. But it is possible to describe the craft in general terms. In figure 2 are sketched possible Apollo configurations for the Earth-orbital, circumlunar, and lunar-landing missions. In all cases, the spacecraft will be rather compact, to minimize its weight and to facilitate the reentry into the Earth's atmosphere.

In order to achieve the multiplicity of Apollo missions, the so-called "modular concept" will be employed in the design of the spacecraft. In this concept, various building blocks, or modules, of the vehicle systems are used for different phases of the mission. The first of these components, which we have called the "command-center module," will house the crew during the launch and reentry phases of the flight; it will also serve as a flight-control center for the remainder of the mission. It will be sufficiently large for a three-man crew.

The second module is a propulsion unit. In Earth-orbital flights this unit will serve to return the craft to Earth under both normal and emergency conditions. It will also be used for maneuvering in orbit and for orbital rendezvous with other satellites. For circumlunar flights, this same propulsion module will be designed so that it can return the spacecraft to Earth safely from any point along the lunar trajectory. For circumlunar flights, also, it will provide midcourse and terminal guidance corrections; and it can place the spacecraft into a satellite orbit around the Moon and eject it from that orbit and return it toward Earth. For the lunar-landing mission, the same propulsion unit will be the takeoff stage from the Moon in order to return the spacecraft toward Earth.

The third module shown on the lunar-landing vehicle is a propulsion stage that will decelerate the spacecraft as it approaches the Moon, and will gently lower it to the Moon's surface.

For the Earth-orbital mission, an additional module can be provided to serve the function of an Earth-orbiting laboratory.

Of all of the modules mentioned, only the command-center unit will be designed with the capability of reentering the Earth's atmosphere and being recovered on the surface of the Earth.

The Apollo spacecraft is therefore seen to be a versatile one; it will involve the development of a number of components, but maximum use will be made of these components for the three Apollo missions.

LAUNCH-VEHICLE REQUIREMENTS

As the Apollo missions progress in difficulty from Earth-orbiting to circumlunar to lunar landing, larger and larger launch vehicles will be required. The three launch vehicles that will be used for the three Apollo missions are shown in figure 3. The Saturn C-1 will be used

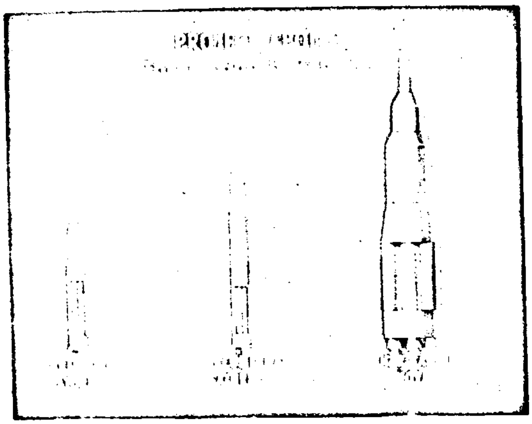

FIGURE 3

for Apollo Earth-orbital flights. It will have the capability of placing the Apollo command center, together with its propulsion and orbiting laboratory units, into an orbit between 150 and 300 miles above the Earth's surface.

In order to accelerate the Apollo spacecraft to escape velocity, which is nearly 1½ times satellite velocity, a more powerful launch vehicle than the Saturn C-1 will be needed. For the Apollo circumlunar flight, therefore, the Saturn C-2 will be employed. The Saturn C-2 differs from the C-1 in that it has a large hydrogen-oxygen-propelled second stage. It will have the capability of sending the Apollo spacecraft and its propulsion unit to the vicinity of the Moon. Both the Saturn C-1 and C-2 are currently under development. Before a manned lunar landing can be made, a launch vehicle that is much more powerful than the Saturn C-2 must be developed. The name given to such a vehicle is Nova. A conceptual version of the Nova vehicle is shown in the figure, roughly to the same scale as the Saturn C-1 and C-2; it may approach one-half the height of the Washington Monument. Nova will employ, in its first stage, either a cluster of 1½-million-pound F-1 liquid-fuel engines, or a cluster of large solid-propellant engines.

LUNAR-LANDING MISSION

The development of the Apollo spacecraft and launch vehicles will require the solution of many scientific and technological problems. In order to identify some of the areas in which major advancements in technology are required, I will briefly discuss an Apollo lunar-landing mission.

Figure 4 illustrates the first phase of this mission; that is, the launch from the surface of the Earth. In the launch area, adequate protection will have to be provided against the hazards of explosion and against the tremendous noise that will be generated by the huge rocket engines. We do not anticipate that it will be possible to design and build such a large launch vehicle that will be completely free of possible malfunctions. Hence, the Nova will have to be equipped with safety devices and sensors that can signal the Apollo spacecraft of an

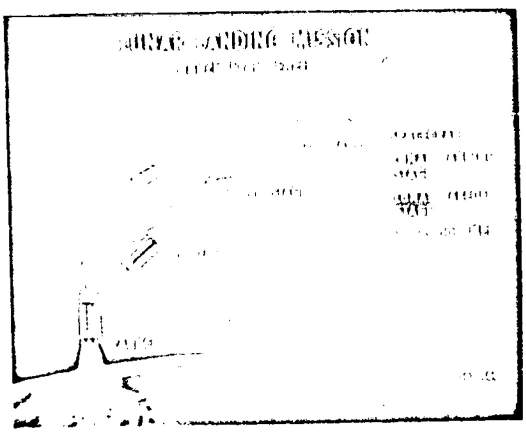

FIGURE 4

impending malfunction, just as the Mercury Redstone and Atlas vehicles are equipped with an abort sensing system. The spacecraft will, of course, be provided with an escape system to allow it to be ejected from the booster and carried to a safe distance. Such an escape system must function reliably at all speeds up to the booster burnout velocity of 25,000 miles an hour.

At least three stages of propulsion will be required to place a spacecraft and the lunar-landing and -takeoff stages at a sufficiently high velocity. The booster guidance system will have to send the spacecraft along a precisely determined trajectory so that only minor corrections will be required during the course of the mission.

Once the spacecraft leaves the Earth's atmosphere, it will be subjected to several types of radiation. It will have to fly through the Van Allen radiation belts, which are of high intensity but of sufficiently low energy to make shielding practicable. Because the time spent in the radiation belts will be short, only a small amount of shielding will be required for this type of radiation. Beyond the Van Allen belts, the spacecraft will be subjected to cosmic radiation. The energies of cosmic radiation are so high that shielding becomes impractical. However, the peak intensity is sufficiently low so that no danger is expected in a lunar mission. The most serious radiation problem results from the particles generated by some solar flares. Some of the major flares, called giant flares, generate particles of such energy and intensity as to make shielding weights prohibitive. However, there are indications that it may be possible to predict these flares, or at least their absence, several days in advance. With such predictions, it would be possible to circumvent the radiation problem by avoiding flights during the time of anticipated major-flare activity. In the past 10 years, only seven giant flares were observed.

The radiation problem, more than any other, requires a great deal of study before manned lunar flight can be achieved. Many of the answers now lacking will be supplied through our scientific satellite and probe programs. The effects of the various types of radiation on living tissues are yet to be determined.

During the course of the flight toward the Moon, the position and velocity of the spacecraft will constantly be assessed and corrections will be made in order to bring the craft into the proper position relative to the Moon. Although sensitive guidance and control equipment will be required, the spacecraft pilots will play a large part in maneuvering their craft.

It is not yet clear whether or not artificial gravity will be required in the Apollo spacecraft. Results from Project Mercury orbital flights, and from our Life Sciences programs, will settle this question.

The actual landing on the Moon is illustrated in figure 5. Although a horizontal landing on

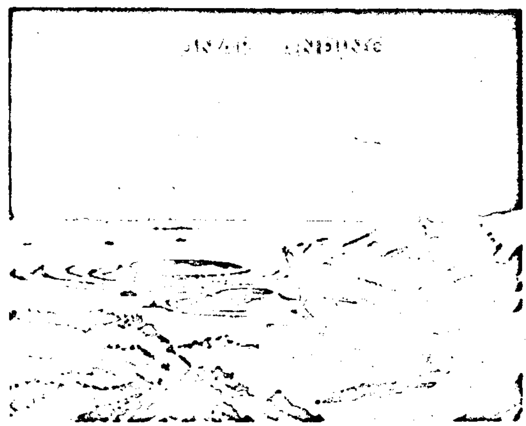

FIGURE 5

the Moon is shown in this figure, vertical landings are, of course, possible. It is anticipated that the landing will be made at a site that had previously been surveyed by an unmanned spacecraft; such a survey is needed in order to determine whether there are any large obstacles in the landing area and to determine the exact characteristics of the landing surface. A precise knowledge of the surface environment, its hardness and its composition, is needed before a manned landing can be made, or before a landing gear can even be designed. The unmanned Ranger, Surveyor, and Prospector programs, described in Mr. Cortright's presentation, will provide us with the information that is needed in this area. Such unmanned spacecraft will also place beacons on the lunar surface that will be used as landing aids for the manned mission.

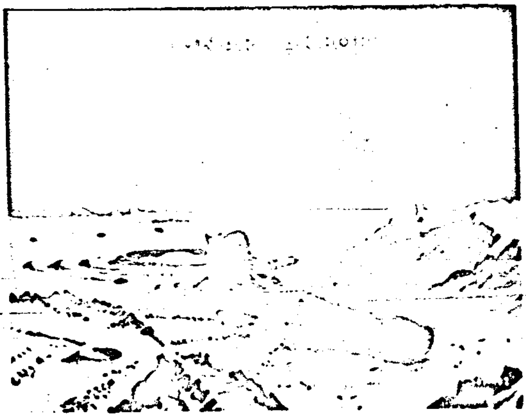

FIGURE 6

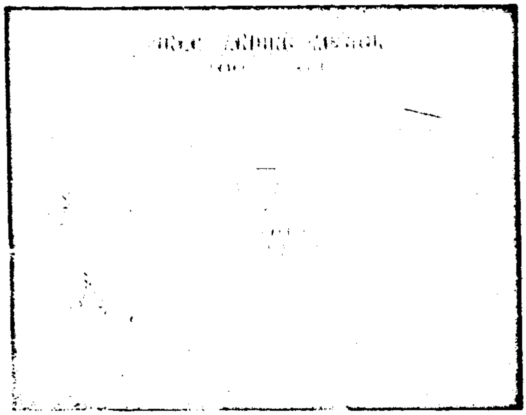

FIGURE 7

The takeoff from the Moon is shown in figure 6. The preparations for such a takeoff will require major advancements over today's operational procedures. All the equipment for the takeoff must be prepared, erected, and checked out by the three men in the spacecraft. When we consider that each current launching from Cape Canaveral involves directly hundreds of people on the launch pad, in the blockhouse, and in the control centers, and indirectly involves thousands more at the checkout and tracking facilities, it becomes clear that the lunar takeoff by three men will be a difficult task indeed.

The propulsion system used for this lunar takeoff must be the most reliable component of the entire Apollo system. The time of takeoff must be precisely planned, and the guidance equipment must work perfectly to place the spacecraft on the proper trajectory for its return flight to Earth.

On the return trip to Earth, the spacecraft must again be steered along a precise trajectory to allow it to enter within the limits of a rather narrow entry corridor into the Earth's atmosphere, shown in figure 7. The boundaries of this corridor are determined by maximum tolerable loads or heating on the one hand, and minimum aerodynamic loads to cause reentry in a single pass, on the other hand. When the spacecraft returns to the Earth's atmosphere, it will again be travelling at a speed of 25,000 miles an hour. At this speed the aerodynamic heating problem is far more severe than it is at satellite velocity. In addition to the convective heating that is encountered on a reentering satellite, an appreciable percentage of the total heating will be caused by radiation. At these speeds the air behind the shock wave will become so hot that it will reradiate a large amount of heat to the surface of the spacecraft. Mr. Ames discusses these problems in more detail.

Although the spacecraft will be rather compact and will not have any wings, its shape will be such that it can generate a moderate amount of aerodynamic lift. Proper control of this lift will allow the spacecraft to maneuver within the reentry corridor and to be guided toward a preselected site. The lack of wings, however, will make it impossible to make a conventional airplane-type landing. Instead, a landing using parachutes or similar devices will be made.

Of course, it has been impossible to describe in this short presentation the real size, the real magnitude, of the job that has to be done in Project Apollo. The project's success depends entirely on the resources, the energy, the determination, and the ability of the people involved. The project will require the best scientific and technical skills available in our schools, our industries, and our laboratories. President Kennedy, in yesterday's message to Congress, stated, and I quote: "No single space project will be more exciting, or more impressive, or more important for the long-range exploration of space; none will be so difficult or expensive to accomplish." The President's message set the stage for this program; it is up to all of us to carry it forward.

PROJECT MERCURY

Let me now return to Project Mercury, and to a discussion of our first manned space flight—Alan Shepard's flight of May 5, 1961.

The purpose of this flight was to determine man's ability to perform useful functions in a space environment. The flight was short—it lasted only 15 minutes. Yet, during this time Shepard was subjected to the accelerations of a rocket launching, peaking at 6 g; to 5 minutes of weightlessness; and to reentry decelerations of 11 g. He carried out the many tasks that were assigned to him, and carried them out exceptionally well; he was in constant voice communication with the ground, and maneuvered the craft during weightlessness and during reentry. Shepard's physiological reaction before, during, and after the flight did not differ from his reactions during earlier ground tests.

I will now show a film of Shepard's flight.

Film Narrative

"Shepard arrived at the launch pad at 5:00 a.m., Eastern Standard Time, on the morning of the launching. He was brought to the pad from the hangar facilities in a transfer van equipped to check his pressure suit and medical instrumentation.

"At the base of the Redstone he paused briefly to examine the booster, just as an airplane pilot checks his ship prior to takeoff.

"Shepard then rode to the top of the gantry in an elevator.

"The countdown clock reads minus 120 minutes—2 hours until launch time, if no holds are necessary.

"On a platform on top of the gantry, another Astronaut, Gus Grissom, wishes him well. Shepard is assisted into the Mercury capsule by a third Astronaut, John Glenn.

"The time is shortly after 5:00 a.m. Once he had entered the capsule, Shepard remained there until the flight was completed, in spite of the fact that several holds were required prior to liftoff. These holds were called as a result of cloud cover in the launch area, and to replace a component on the Redstone.

"The launching took place at 9:34 a.m.; Shepard had been in the capsule for more than 4 hours.

"The countdown approaches zero: six, five, four, three, two, one,—liftoff.

"Liftoff was smooth, and Mercury Redstone-3 is on its way.

"In the next scene you will see a film of Shepard taken during the flight. You will hear Shepard's voice as he reported in flight: you will also hear, less distinct, Deke Slayton's voice as he talked to Shepard from the ground. The scene starts just moments before liftoff.

Slayton: 15, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, zero. Liftoff.

Shepard: Roger, liftoff, and the clock is started.

Slayton: OK—you're on your way.

Shepard: Yes sir, reading you loud and clear.

Slayton: Roger, trajectory OK.

Shepard: This is Freedom Seven, the fuel is go. 1.2 g: cabin at 14 psi; oxygen is go.

Slayton: Trajectory looks good.

Shepard: Freedom Seven is still go.

Slayton: Roger.

Shepard: This is Seven, fuel is go; 1.8 g: 8 psi cabin; and the oxygen is go.

Slayton: Roger, trajectory OK.

Shepard: Cabin pressure is holding at 5.5.

Slayton: Roger.

Shepard: Cabin holding at 5.5.

Slayton: Understand; cabin holding at 5.5.

Shepard: Fuel is go; 2.5 g. Cabin 5.5, oxygen is go, the main buss 24, and the isolated battery is 29.

Slayton: Roger.

Shepard: OK. It is a lot smoother now. A lot smoother.

Slayton: Roger.

Shepard: Seven here. Fuel is go; 4 g; 5.5 cabin; oxygen. All systems go.

Slayton: All systems go. Trajectory OK.

Shepard: Cutoff. Tower jettison green.

Slayton: Roger.

Shepard: Disarm.

Slayton: Roger.

Shepard: Cap sep. is green.

Slayton: Roger. Periscope is coming out.

Shepard: Periscope is coming out and the turnaround has started.

Slayton: Roger.
Shepard: ASCS is OK.
Slayton: Roger.
Shepard: Control movements.
Slayton: Roger.
Shepard: OK. Switching to manual pitch.
Slayton: Manual pitch.
Shepard: Pitch is OK.
Slayton: Roger.
Shepard: Switching to manual yaw.
Slayton: I understand. Manual yaw.
Shepard: Yaw is OK. Switching to manual roll.
Slayton: Manual roll.
Shepard: Roll is OK.
Slayton: Roll OK. Looks good here.
Shepard: On the periscope. What a beautiful view.
Slayton: I'll bet it is.
Shepard: Cloud cover over Florida, three to four tenths near the eastern coast. Obscured up to Hatteras.
Slayton: Roger.
Shepard: Can see Okeechobee. Identify Andros Island. Identify the reefs.
Slayton: Roger. Countdown on retro: 5, 4, 3, 2, 1, retro-angle.
Shepard: Start retro sequence. Retro-attitude on green.
Slayton: Roger.
Shepard: Control is smooth.
Slayton: Roger, understand, all going smooth.
Shepard: Retro 1 very smooth.
Slayton: Roger, roger.
Shepard: Retro 2.
Slayton: Roger.
Shepard: Retro 3.
Slayton: Roger.
Shepard: All 3 retros are fired.
Slayton: All fired on the button.
Shepard: OK. Three retros have fired. Retro jettison is back to on.
Slayton: Roger. Do you see the booster?
Shepard: Negative.
Slayton: Roger.
Shepard: Switching to fly-by-wire.
Slayton: Fly-by-wire. Understand.
Shepard: Roll is OK.
Slayton: Roger.
Shepard: Roger. Do not have a light.
Slayton: Understand; you do not have a light.
Shepard: I do not have a light. I see the straps falling away. I heard a noise. I will use override.
Slayton: Roger.
Shepard: Override used. The light is green.
Slayton: Telemetry confirms retrojet.
Shepard: Ahh, Roger.
Slayton: Roger.
Shepard: Periscope is retracting.
Slayton: Periscope retracting.
Shepard: I'm on fly-by-wire; going to reentry attitude.
Slayton. Reentry attitude. Roger. Trajectory is right on the button.
Shepard: OK, Buster. Reentry attitude. Switching to ASCS normal.
Slayton: Roger.
Shepard: ASCS is OK.
Slayton: Understand.
Shepard: Switching HF for radio check.
Slayton: Switching on HF.
Shepard: Ahh, Roger, reading you loud and clear. HF, Deke, how me?
Slayton: ------
Shepard: Reading you loud and clear. HF, how me?
Slayton: ------
Shepard: This is Freedom Seven.
Slayton: Coming through loud and clear.
Shepard: "g" buildup 3, 6, 9.
Shepard: OK—OK.
Shepard: OK.
Shepard: OK.
Slayton: Your impact will be right on the button.
Shepard: This is Seven, OK.
Shepard: 45,000 feet now.
Shepard: 40,000 feet.
Shepard: I'm back on ASCS.
Shepard: 35,000 feet.
Slayton: CapCom I can read you now.
Shepard: Ahh, Roger, Deke, loud and clear. How me?
Slayton: Switching over to G.B.I.
Shepard: The drogue is green at 21,000. The periscope is out. OK at drogue de-

ploy, 70 percent auto, 90 percent manual. Oxygen is OK.

Slayton: CapCom, can you read?

Shepard: And snorkels at about 15,000 feet.

Slayton: Roger.

Shepard: Emergency flow rate is on.

Slayton: Roger.

Shepard: Standing by for Main.

Shepard: Main on green.

Shepard: Main chute is reefed.

Shepard: Main chute is green. The main chute is coming unreefed and it looks good.

Shepard: Main chute is good. Rate of descent is reaching about 35 feet per second.

"The landing point, predicted at the moment of Redstone burnout, was radioed to ships and aircraft in the recovery area. Helicopters took off from the carrier, the Lake Champlain, while Shepard's flight was still in progress, and actually had the capsule in sight during its descent.

"The first visual sighting was on a white puff of smoke, caused when the remaining hydrogen peroxide fuel was dumped.

"Now the main parachute is visible.

"Moments after landing, one of the helicopters hooked on to the capsule. Shepard had the choice of remaining in the capsule while it was carried back to the carrier, or being hoisted from the capsule into the helicopter; he elected to ride in the helicopter, and was hoisted, with a personnel sling, from the capsule to the same helicopter that you now see lifting the capsule.

"The entire flight had lasted 15 minutes; 6 minutes after landing, the capsule was out of the water, and 5 minutes later, it was on the carrier's deck.

"The time is 10:00 a.m.; just 26 minutes after liftoff. The capsule is being secured on deck.

"In the past 26 minutes Shepard had been accelerated to a speed of 5100 miles per hour, flown to a height of 117 miles, a distance of 302 miles, and had then been brought, by helicopter, to this aircraft carrier.

"And here is Alan Shepard, getting out of the helicopter—still wearing his pressure suit.

"He had performed his mission well. Although the masses of data are still being analyzed, we know now that no unexpected results were encountered.

"A full report of all the results will be given in a technical conference in Washington, sponsored jointly by the National Academy of Sciences, the National Institutes of Health, and NASA, in ten days.

"You now see Shepard below decks, taking off his pressure suit.

"And here, less than half an hour after completion of the flight, Alan Shepard is speaking by telephone with President Kennedy. This country's first step into space had been a complete success."

In our manned space-flight program we have accepted a tremendous challenge. We have come a long way in the past two years; the work ahead will not be easy. But we can and we must succeed in this great undertaking.

NASA SPACE FLIGHT PROGRAMS

5. RESEARCH FOR THE SPACE AGE

by Milton B. Ames, Jr.*

INTRODUCTION

The program has thus far dealt mostly with space-flight missions. They, of course, represent the part of our nation's space activities that are mostly in the public eye. My presentation concerns NASA's advanced research for the space age.

As a consequence of the expansion of our nation's interest in science and technology, the word "research" has been used to describe many different activities; in my remarks, the word "research" is taken to mean the process of seeking new knowledge. There is a famous Latin quotation which, simply stated, means, "Knowledge is power."

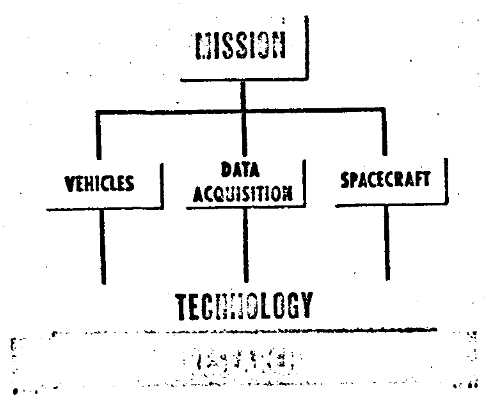

FIGURE 1

Figure 1 will help you to understand the role of research in our nation's space program. Starting at the bottom of the figure, you can see that research provides a foundation for the next upward, advanced technology, which in turn supports the various activities and items such as vehicles and spacecraft necessary for the accomplishment of our ultimate objectives, the space-flight missions, shown at the top.

Research advances the general technology by identifying and defining significant problems standing in the way of accomplishment of future missions. Research also develops information for the solution of these problems. Basic research generates new and advanced concepts and ideas, which permit significant advances over those obtained from day-to-day developments of existing flight technology.

The greater part of the advanced laboratory research conducted by NASA is performed at the Langley, Ames, Lewis, and Flight Research Centers. Smaller but highly significant contributions are also made by the Goddard and Marshall Space Flight Centers and the Jet Propulsion Laboratory. NASA advanced research is also conducted under contract or grant by the nation's universities, research institutions, and industry.

Let's consider a typical space-flight mission, in order to identify some of the problems confronting us and to describe the relationship of our research activities in providing solutions to these problems (fig. 2). The space mission deals with (1) launch and exit from the atmosphere; then (2) space flight; and, finally, (3) reentry and landing.

LAUNCH AND EXIT

In figure 3, we see that the launch and exit phase of any space mission generates research problems in many technical areas. They may be lumped broadly into three categories:

(1) Propulsion

*Deputy Director, Advanced Research Programs, National Aeronautics and Space Administration.

(2) Materials and structures
(3) Guidance and control.

PROPULSION RESEARCH

First, I would like to discuss propulsion research, which is one of the most critical and important problem areas for space missions. Our present research efforts are concentrated on three main types of rocket—chemical, nuclear, and electric. The performance potential and future promise of these three types of rockets may be summarized with the aid of figure 4. Shown on the ordinate is the gross weight of the space vehicle at launch required to achieve certain velocities (the abscissa scale) for the chemical-, nuclear-, and electric-rocket systems. Earth-orbital missions require velocities of about 25,000 feet per second, or 18,000 miles per hour. Interplanetary missions require velocities greater than 36,000 feet per second, or in excess of speeds of 25,000 miles per hour. Velocity requirements for lunar missions fall, of course, in between those for orbital and interplanetary missions. Obviously, as the velocity requirement increases, the more difficult the mission becomes.

We see from the figure that the chemical rocket requires the largest vehicle, the nuclear rocket the next in size, while the electric rocket holds out promise of the smallest vehicle for the most difficult missions. We can see also that the most dramatic gains in using nuclear and electric propulsion are out in the high-velocity range required for the interplanetary missions where the chemical rocket is far too heavy and in certain missions cannot with any reasonable size reach the high velocities that are required. Chemical-rocket systems are essentially available to us now; nuclear rockets will come later in time, but will be available prior to very powerful electric-propulsion systems.

The thrust of the chemical rocket is limited by the energy content of the fuel and the oxidizer. Research on high-energy fuels conducted at the Lewis Research Center has already resulted in the use of hydrogen and oxygen in the Centaur rocket and the upper stages of the Saturn vehicle.

Figure 5 shows one of the hydrogen-burning Centaur rocket nozzles being readied for tests at the Lewis Research Center. The Centaur

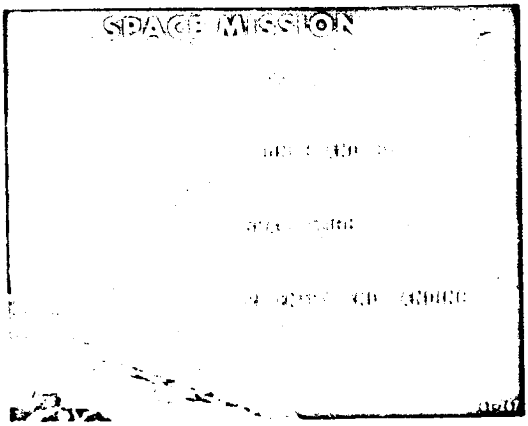

FIGURE 2

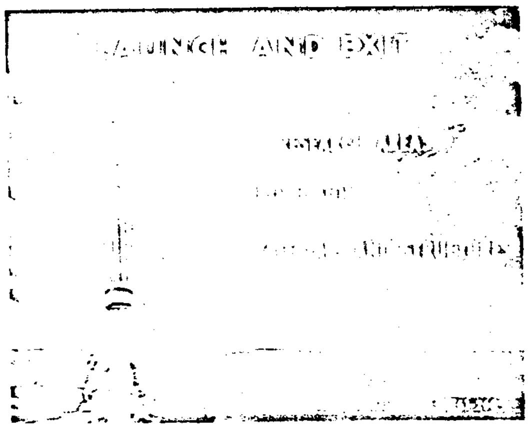

FIGURE 3

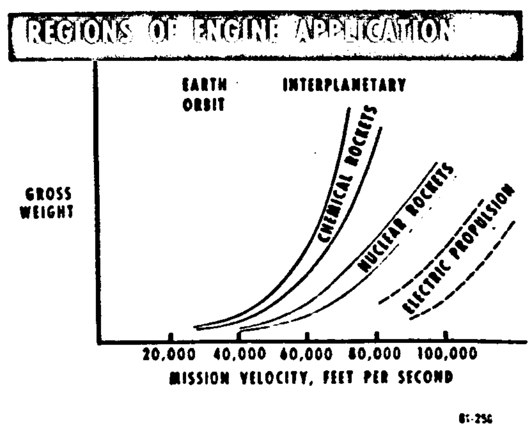

FIGURE 4

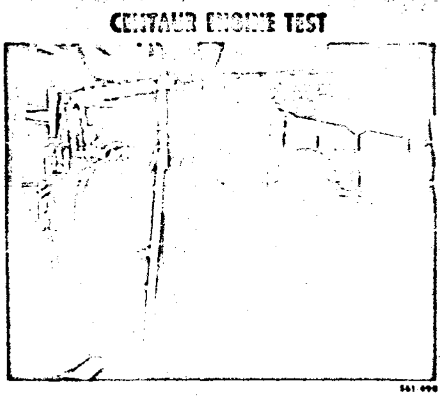

Figure 5

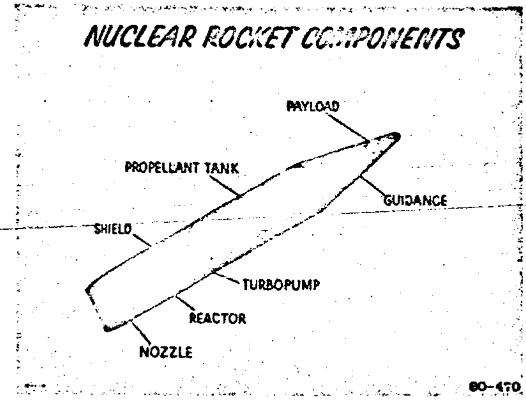

Figure 6

rocket, which will be mounted on top of an Atlas, will be used to extend our nation's capability of exploring interplanetary space in the not too distant future. While research is continuing on high-energy propellants, the outlook is uncertain, and we seem to have reached the limit of chemical fuels.

Figure 6 is a schematic diagram of the components of a nuclear rocket. The difference between the nuclear rocket and the chemical rocket is that the reactor provides us with the means of heating the hydrogen propellant to extremely high velocities that are two or three times the value that we can achieve in our hydrogen and oxygen chemical-rocket combustion systems. While we find that there is plenty of energy in the nuclear rocket system, the problem is to use this energy in a practical way. The AEC and the NASA are working cooperatively on the Rover Project, and also undertaking fundamental research looking toward improved nuclear-rocket systems. Mr. Finger discusses this work in a later paper. Obviously, the nuclear rocket has an important part to play in our space program, especially for the more difficult space missions.

The electric rocket offers very large increases in specific impulse (or efficiency of utilization of propellant), and offers great potential for use in deep-space missions, such as flights to Mars and Venus. Figure 7 shows schematically an electric rocket of the nuclear-turboelectric type. An electric rocket is attractive because it will produce extremely high jet velocities

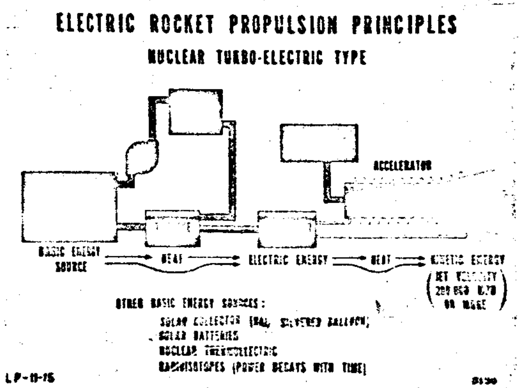

Figure 7

(on the order of 200,000 mph). The propellant is ionized (i.e., given a positive charge); it is then passed through an electrostatic field, which accelerates the positively charged propellant out the nozzle at very high velocities. The large amounts of electrical energy required for the electrostatic field and the ionization of the propellant are obtained from a nuclear reactor through a turbine-driven electric-generator system, as shown in the figure. Mr. Finger also describes NASA's work on this type of propulsion system in his paper. I would like to state, however, that our research on electric rockets has already resulted in small laboratory ion accelerators (the rocket-nozzle part of the system shown in the figure) that have operated at unprecedented high efficiencies and show promise of long endurance and reliability.

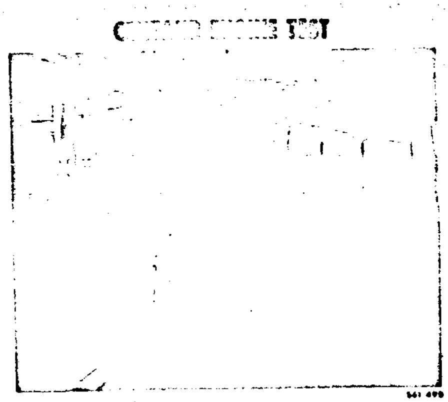

FIGURE 5

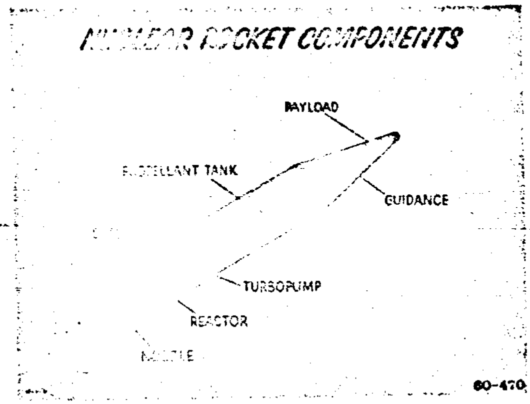

FIGURE 6

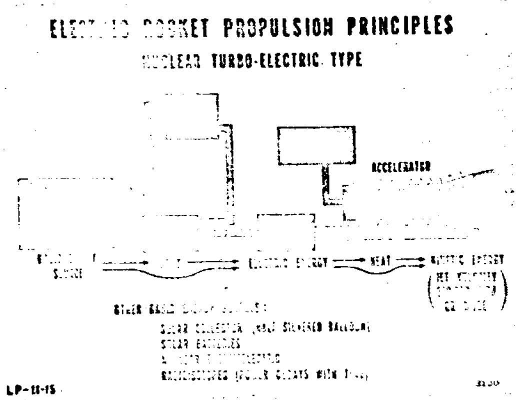

FIGURE 7

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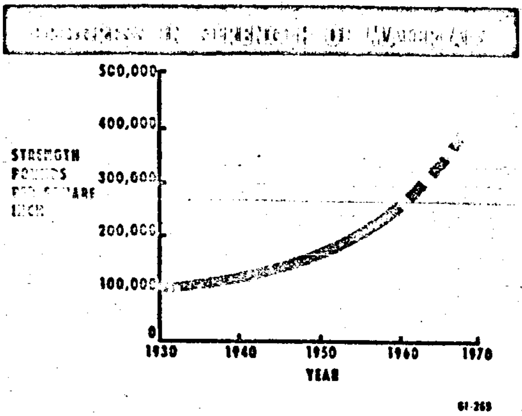

FIGURE 8

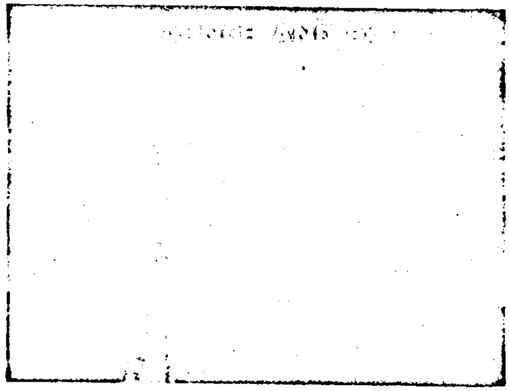

FIGURE 9

MATERIALS AND STRUCTURES

Structures and materials problems during the launch and exit phases of our space-flight mission spring from two basic requirements:

(1) The necessity for the lightest possible weight

(2) The necessity for reliable structural performance in severe environments.

One method by which we can minimize the weight of a launch vehicle is to use high-strength materials. Figure 8 shows how the strength of materials in pounds per square inch has been improved over the years. Today, our designs are based on strengths up to 240,000 pounds per square inch, and presumably if our research is successful we will be able to achieve strengths as high as 500,000 pounds per square inch—perhaps during this decade.

While new high-strength materials appear to be very attractive, there are, however, numerous problems in utilizing them. Perhaps the most difficult of these problems is that of brittleness or loss of toughness. As the strength of the material is increased, it tends to become brittle. In the embrittled state, the materials are very sensitive to minor amounts of corrosion that occur during normal storage, minor imperfections in manufacture, and stresses and strains imposed by normal handling. An important part of our research, therefore, is to gain an understanding of what constitutes toughness and how we can retain this important property in the new high-strength materials in space-flight applications.

Another related problem is that in space flight the materials must operate at the very low temperatures of liquid oxygen, hydrogen, and fluorine. There is, at present, little experience in the design of minimum-weight structures for use at these very low or (as they are sometimes called) cryogenic temperatures, and this is a formidable problem to which we are devoting considerable emphasis in our research.

Now let's consider the severe environment of the vehicle during flight through the atmosphere on the way to space (fig. 9). All of you have seen pictures of a large rocket in its initial phase of flight as it leaves the launching pad. It appears to rise slowly and majestically, but as it ascends it steadily gathers speed, and before it leaves the denser part of the atmosphere it is traveling at a very high rate. Typically, a launching vehicle at a height of 35,000 feet would be subjected to steady air pressures of 1,000 pounds per square foot or more at the nose. This is 40 times the force produced by a 100-mph hurricane, and gives some indication of one of the critical environmental influences the vehicle must withstand.

Because the launching vehicle is large, slender, and flexible, severe buffeting or unsteady loads result if the air does not flow smoothly over the vehicle. Also, at a speed slightly faster than the speed of sound, shock waves are formed that cause the flow over the vehicle to fluctuate.

"In this motion picture, we see a model of an Atlas booster, with a Mercury capsule mounted on its nose, being tested in a wind tunnel. The airflow, which is from your right to left, is made visible by what is known as the schlieren technique. The model is complete, even to the escape tower, which can be seen on the right. At a speed slightly supersonic, shock waves are formed around the model and fluctuations of the flow are visible."

Structural loads produced by such unsteady flows must be accounted for in the structural design of the launch vehicle. By means of research studies in wind tunnels, and also by detailed pressure measurements in flight, we are developing the knowledge from which these buffeting forces can be alleviated or from which more accurate predictions of the structural stresses can be made. The objective then of our research is to furnish the designer with sufficient knowledge to design lightweight, efficient, and reliable structures.

SPACE FLIGHT

During the exit of our vehicle from the atmosphere, we have been concerned with devising lightweight structures that are capable of withstanding large loads and sudden accelerations. In space, the situation is quite different. Our principal research areas are shown in figure 10. They are (1) space environment, and (2) navigation and control.

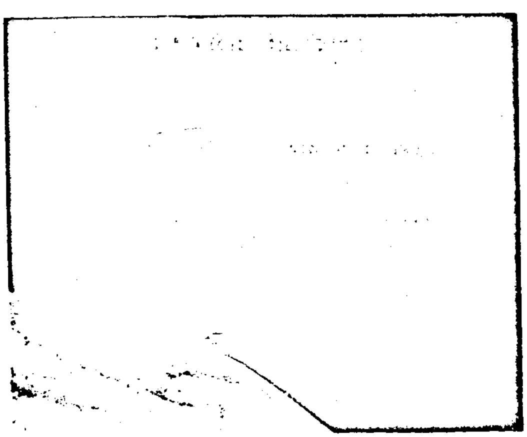

FIGURE 10

SPACE ENVIRONMENT

One important problem associated with space environment in the design of space vehicles is protection against meteoroids. We are trying to define the magnitude of the hazard that meteoroids impose. Using the best available (but still fragmentary) knowledge of the numbers and sizes of meteoroids in space, together with present theories of the damage produced by them, we arrive at the situation illustrated in figure 11.

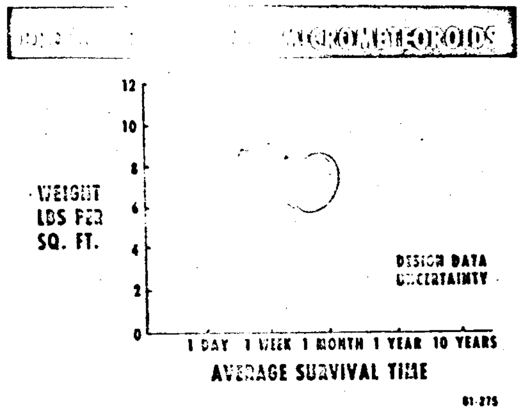

FIGURE 11

In this figure, we have plotted the weight of the outer skin of the vehicle, in pounds per square foot, using both optimistic and conservative estimates from current theories. This weight is plotted against an average survival time for one meteoroid penetration. Obviously, if a man were in the vehicle, even one penetration might be excessive. The area of uncertainty is the dark region whose upper boundary represents the pessimistic estimate. The point is that, regardless of the survival time required—a day, or a year, our present knowledge does not enable us to specify the shielding required. If we use the conservative estimate, the weight required is about eight times that required for the optimistic estimate for the case of the longer missions. This fact emphasizes our need for better data.

Figure 12 shows, on the left, the crater made by an actual meteoroid impact on a sounding rocket. It occurred at an altitude of about 90,000 feet within the atmosphere: consequently,

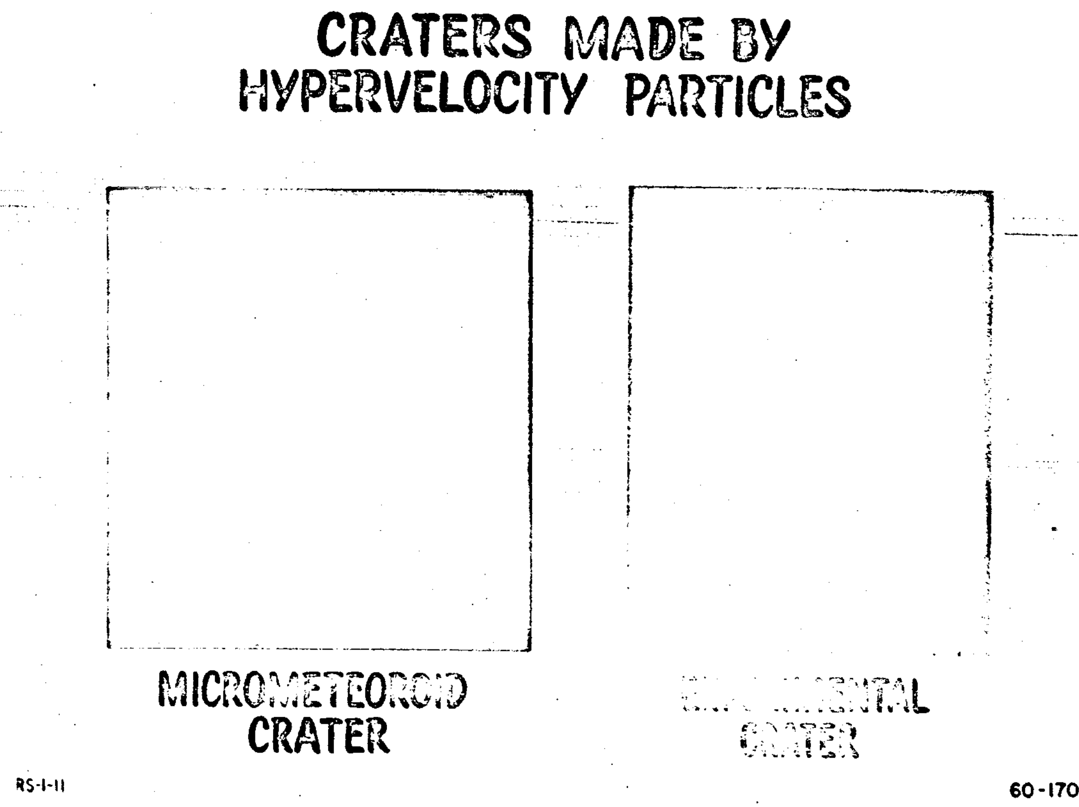

FIGURE 12

the meteoroid must have been greatly slowed down from its original speed by the atmosphere above this level. The rocket itself was traveling at only about 3000 miles an hour. The impact was therefore much slower than those we expect to encounter in space. Nevertheless, the incident is of great interest in demonstrating that impacts actually do occur.

Intimately coupled with our need for a better assessment of the number and size of meteoroids that we might encounter is a need to evaluate the damage that each can create. To study this problem, we have to develop capability for creating impact at meteoroid velocities under controlled conditions in a laboratory facility on the ground. On the right is a photograph made in an NASA laboratory of an impact crater made by shooting a small steel ball at a copper target. This comparison simply shows the similarity of the two craters, one made by a micrometeoroid in space, and the other by a particle shot from a gun in the laboratory.

Within the past year, for the first time, we have achieved velocities at the lower limit of the speed of meteoroids (30,000 ft/sec); and of equal importance is the fact that the methods for achieving even higher speeds in the laboratory are now evident.

NAVIGATION AND CONTROL

Now let us turn to spacecraft navigation and control. Shown in figure 13 are three typical space flights: (1) an Earth satellite, (2) a lunar circumnavigation and return to Earth, and (3) a planetary probe.

We are conducting research on all of these missions, and have concentrated on four problem areas:

(1) Trajectories (the flight paths required

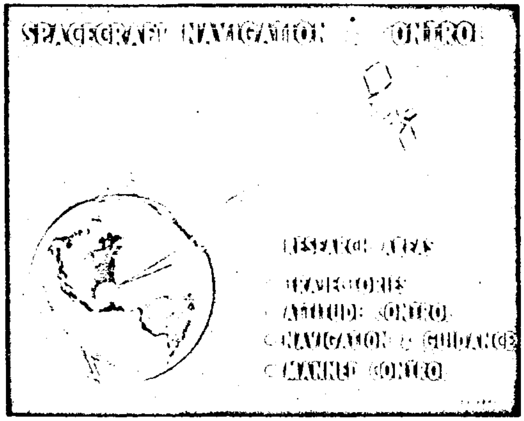

FIGURE 13

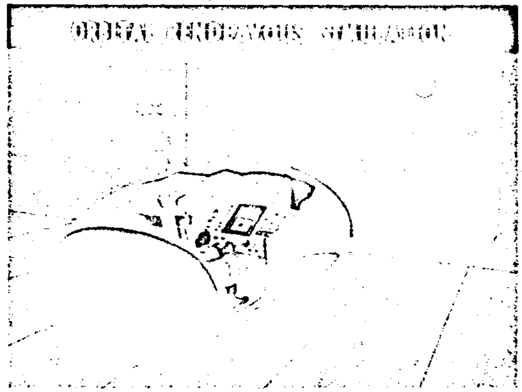

FIGURE 14

for mission accomplishment) are receiving intensive study. As an example, recent studies of a lunar circumnavigation flight, with return to Earth, show that certain trajectories will reduce the miss distance at the Earth and in turn reduce the power required for the flight-path correction.

(2) Attitude control, which is needed for proper orientation of the spacecraft in such functions as astronomical observation or thrust application to change position of the spacecraft, is another important problem area.

(3) Navigation and guidance are the matter of knowing where you are, where you want to be at some future time, and how to get there. Much of our research on navigation and guidance is concentrated on manned lunar flight; however, flights to the near planets are receiving increased attention.

(4) Much research has been undertaken on manned control (or the role of man in controlling the spacecraft). Results of these studies have already been applied to the X–15, Project Mercury, and the U.S. Air Force Dyna Soar.

In addition, we are giving some attention to the special problems of a spacecraft performing a rendezvous with another craft in space, as shown in figure 14.

Space rendezvous is the process of bringing together two spacecraft at some predetermined point or time in space. For example, it permits assembly of components in space and therefore results in a larger vehicle in space than could be placed there by a single launch vehicle. Rendezvous also permits the performance of special functions such as supply, maintenance, and crew transfer.

One aspect of our studies of the ability of man to control spacecraft relates to the terminal phase of rendezvous in space. We have considered instrument as well as visual flight through the use of ground-based flight simulators, shown in the figure. The simulator consists of a cockpit that provides the astronaut with spacecraft controls, appropriate flight instruments, and a view of the simulated outside space. Through these simulator studies, we are led to the tentative conclusion that man will be able to control the terminal phase of a space rendezvous.

REENTRY FROM SPACE

Let us now turn to the problem of the entry of space vehicles into the atmosphere of the Earth or that of other planets (fig. 15). The eternal reentry problem, of course, is that of heat generated by the atmosphere. The tremendous kinetic energy of the spacecraft has to be converted into other forms of energy, mostly mechanical and heat energy, in order to slow the body down to avoid burning and other structural destruction.

The last phase of a manned lunar mission during reentry into the Earth's atmosphere poses much more severe problems of guidance and control, deceleration, and heating of the vehicle than will be experienced by the Mer-

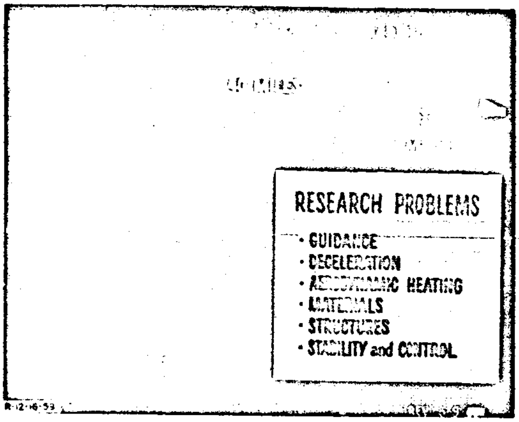

FIGURE 15

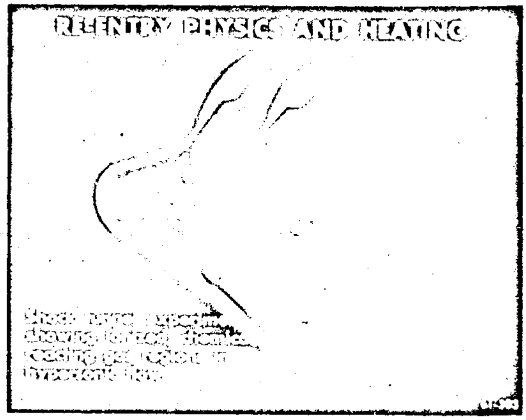

FIGURE 16

cury capsule on reentering the atmosphere at satellite velocities. Perhaps you can visualize, with the aid of figure 15, a spacecraft traveling from a distance of a quarter-million miles out in space and heading toward the Earth at a speed of 25,000 miles per hour. In order to decelerate and land safely in its first pass around the Earth, the simple ballistic capsule shown must enter a flight-path corridor with an accuracy of only 3½ miles above or below the proper trajectory. For scale, this corridor width is less than 1/1000 of the diameter of the Earth. In this figure, the width of the line representing the entry-corridor trajectory has been exaggerated about ten times to permit you to see it. Present guidance technology is not capable of meeting this stringent requirement in a practical way. If our capsule undershoots this corridor, the occupants will be destroyed by the high deceleration forces or burn up in the atmosphere. On the other hand, if it overshoots the corridor, our manned vehicle will make another excursion out into the great radiation belts involving the probability of several additional days of flight, if indeed it can return to the Earth at all. We are, of course, extending our work on guidance and trajectory control to find means of meeting the severe accuracy requirements imposed by the ballistic type of vehicle.

We are also conducting research on other concepts, such as the half-cone lifting body shown in the figure. Results indicate that the permissible entry-corridor width might be increased to perhaps 40 miles by the use of limited amounts of lift. This concept would, of course, greatly alleviate the guidance problem and also reduce the accelerations experienced by the astronauts.

Naturally, we would like to have a wider corridor. Unfortunately, however, a vehicle with enough lift to have a wider corridor would be heavier and subject to fantastically high heat loads and temperatures. We simply do not know enough about high-temperature materials and structures to build a vehicle for a very wide corridor.

We have concentrated much research on reentry from deep space during the past year and have made substantial progress in the problem areas shown in figure 15: guidance, deceleration, aerodynamic heating, materials, structures, and stability and control.

Figure 16 shows an experiment with a model capable of using small amounts of lift in one of the NASA's advanced "wind" tunnels. Here the model is located in a so-called shock tunnel with an airstream having a duration of about a millisecond. Since the speed is well above 12,000 feet per second, the air undergoes chemical changes indicated by the luminescent regions on the model. The study of the flow pattern on this figure, which is from left to right, shows very clearly the regions of maximum air temperature. We learn about the heat transfer, the atmospheric friction, and also the chemical processes of ionization of the atmosphere that produce the electro-fluid-dynamics phenomena in the vicinity of the body, which cause radio blackout and hence play an important part in the communication with the space vehicle.

We are continuing research and development on these complex problems for a variety of reentry bodies, thus giving the designer a selection to suit his requirements.

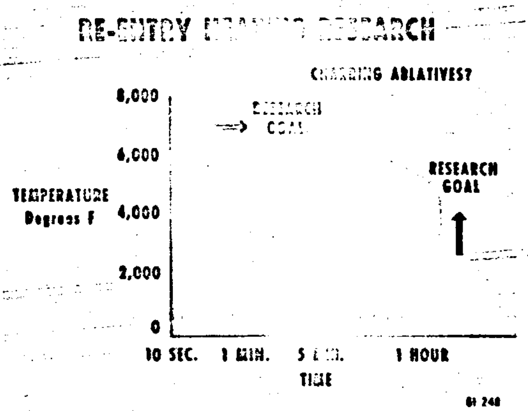

FIGURE 17

Figure 17 illustrates the present status of research relating to the protection of the structure from the high temperatures of atmospheric entry. I have plotted temperature against heating time, varying from a few seconds to more than 1 hour. Intercontinental-ballistic-missile nosecones fall in the extreme left-hand part of this chart. I have also indicated the general region for the Mercury vehicle and that for reentry from advanced manned flight from the Moon. Various parts of this region represent conditions on different parts of the lunar vehicle from the nose to the stern, and the conditions likely to be encountered by variations of guidance accuracy. The shaded areas of the chart represent the types of solutions shown by research to be most desirable for the various conditions of temperature and duration, and also the research goals of providing for higher-temperature protection for longer times. The lower left-hand region of the figure, where the temperatures are relatively low for short periods, is the region where sufficient protection can be provided simply by using a heavy metal cover as a heat sink, which will not become too hot in the short time of exposure. For the lower temperatures and longer times, protection can be provided by radiation cooling of refractory materials. For flight conditions for higher temperatures and short times, ablating materials that vaporize will provide protection. This system is used for Mercury and for advanced ICBM nosecones.

Thicker ablating material will, of course, protect for longer times, but there is a limit to the practicality of just increasing the material thickness. Charring ablatives are showing much promise for the combination of high temperatures and long exposures. Much research remains to be done with these materials, but we think we are on the right track to provide heat protection for the reentry of vehicles from deep space.

X-15 FLIGHT-RESEARCH PROGRAM

I would like to conclude my talk with a brief report on the X-15 flight-research program. Mr. Bikle deals with this program in more detail later.

In 1954 the NACA (predecessor of the NASA) recommended, on the basis of results of research that it had conducted, that a flight vehicle like the X-15 was feasible and should be built and flown for research and operational experience, as a stepping stone to manned hypersonic and space flight. The X-15 research airplane program is a cooperative effort of the Air Force, the Navy, the NASA, and industry. We have now reached the stage where the X-15 is being used for its intended purpose as a flight-research vehicle. The flight-research program began last year; altitudes as high as 32 miles have been reached, and the maximum speed achieved has been 3307 miles per hour.

In addition to setting new records, more importantly, this program is yielding us much valuable technical data. Flight results to date have demonstrated that well-controlled airplane-type landings can be made by space-type vehicles. The most interesting flights still lie ahead of us. In order to take full advantage of the potential performance of the X-15, we will conduct an aggressive flight program, and plan to use all three X–15's before the end of the calendar year to achieve maximum speed and altitude capabilities.

I would like to show you now a film sequence of a flight of the X–15.

Film Narrative

"The X–15 is mounted beneath the right wing of the B–52 mother ship. Now you can see the nozzle of the large rocket engine. The X–15 drops away from the mother ship at altitudes around 40,000 feet. Now the engine has lighted. The airplane accelerates and climbs very rapidly, since it has 55,000 pounds of thrust. The view you are seeing was taken by a camera looking from the rear of the pilot's canopy. Notice how fast the X–15 is accelerating. If you watch closely, you can see it leave the two F–104 chase planes far behind. Drag brakes are used to slow the airplane down from time to time to keep within the speed prescribed for this particular mission. You will also notice the horizon as the airplane banks and turns sharply. The vapor seen is due to the exhaust of the auxiliary power units. From time to time the engine is cut off and restarted, as shown by the larger vapor trail. The reaction or space controls are also shown in operation. Now we see the X–15 approaching Edwards Air Force Base for the landing. The rocket fuel has been exhausted, so the airplane is gliding without power. You will see the landing skids come down just before touchdown. The X–15 lands as speeds between 175 and 200 miles per hour. After touchdown it takes about 5000 feet, or 1 mile, for the airplane to stop."

Our experience with the X–15 serves to emphasize an important point about research. Here we have just seen on film the results of a strenuous and cooperative effort in research, development, and engineering. In 1954 the X–15 was only an idea in the minds of researchers. Engineering design started in 1955. I believe that this illustrates the long lead-time aspect of research activity. In time, the results of many of the research studies I have discussed with you will find their way into our country's space vehicles.

NASA SPACE FLIGHT PROGRAMS

6. LIFE SCIENCES PROGRAMS

by Alfred M. Mayo*

Space presents a frontier of unequaled mental, physical, and scientific challenge to man. It is characterized by environments completely unfriendly to human survival. The successful achievement of space flight can unlock unlimited potential for knowledge and application.

When a man ventures from the protective atmosphere and electromagnetic shields of his native Earth, he becomes totally dependent upon the artificially created atmosphere and the protective systems of his spacecraft.

The Life Sciences Programs are designed (1) to ensure that knowledge is available for optimum utilization of human capability in all phases of space exploration, and to ensure survival of human crews; and (2) to implement the gathering of knowledge about life from beyond the Earth.

"Aerospace medicine" is concerned with an understanding of the human psychophysiology and the mechanisms by which the human systems react to changes in environment. Figure 1 illustrates the complex of environment hazards, each of which must be controlled to levels consistent with human needs.

Aeromedical research carried on for aircraft flight has provided a considerable amount of the information necessary concerning the effects of acceleration forces, of noise and vibration, the needs for oxygen, and for cabin pressure and temperature control. It was this background of information that was tapped to develop the Mercury capsule system and to provide the protection needed for the first small ventures into space.

Future flights will be of much longer duration; many of them will be outside the protective influence of the Earth's atmosphere and magnetic and other fields. Before the flights can be safely and effectively carried out, it is essential that knowledge be gathered to define environments to ensure adequate protection and conditions conducive to effective human performance.

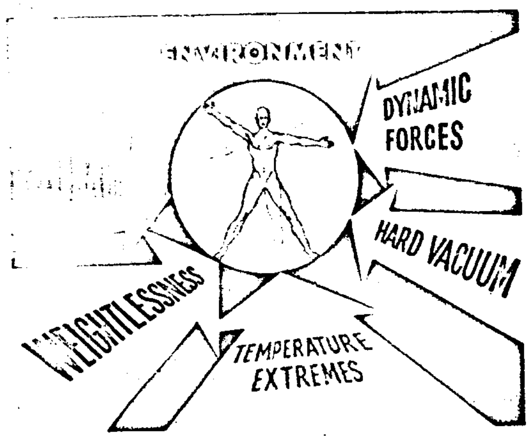

Figure 1

Basic knowledege is lacking concerning the prolonged effects of reduced gravity and weightlessness. The extent of the threat and the protection required against the vast spectrum of unshielded radiations in space must be defined. Probing must continue to determine if other environmental factors, either presently unknown or considered unimportant on Earth, will require consideration. The effects of combinations of environmental stresses must be determined as a function of time in order that the necessary design specifications can be made available. To meet these needs, it is necessary to understand how each of the vital body systems reacts to each of the potential changes in

*Acting Deputy Director, Life Sciences Programs, National Aeronautics and Space Administration.

environment. Some of these reactions are known; some can be determined by ground experiments; and others will require biological experiments in actual space flight. The biological information required from actual flight test is of critical importance. Lack of these data could delay subsequent steps in space exploration.

The Russians have given high priority to their biological flight program, as evidenced by seven major flight experimental systems for biological information.

Information from actual flight experiments is needed in the field of high-energy ionizing radiation effects. It is necessary to study changes in the blood and the circulatory system; in the brain and the nervous system; the digestive system; and in fact to varying degrees, in each of the body systems. Potential damage to the reproductive and genetic system is of particular concern in radiation studies. Because these effects may not be apparent for several generations after exposure, it is important that means of estimating the longer-term effects be included. Fortunately, methods have been developed to use rapidly replicating lower life forms to estimate possible long-term radiation damage to the human reproductive system.

Flight programs have been designed to get results not obtainable in the Earth laboratories.

Balloons are being flown above 90 percent of the atmosphere at northern latitudes where the effects of cosmic particles can be studied. Biological specimens from flights at Bemidji, Minnesota, are now being studied; additional flights are scheduled for Fort Churchill, Canada.

The lower Van Allen Radiation Belt provides a gigantic laboratory with mixtures of high-energy protons unavailable in any present Earth laboratory. To tap this laboratory potential, specimens of bread-mold spores Neurospora, which have been extensively used in radiation studies, were flown into this radiation belt aboard the Nuclear Emulsion Recovery Vehicle in June of 1960. A greater incidence of deformities in succeeding generations of the exposed spores than expected from the radiations measured was observed. These results indicated the need for a more comprehensive program to determine the cause of these changes and to develop technology for additional important research. New tests using a modified vehicle with much more extensive biological experiments are scheduled for this Fall. Future radiation-study projects will require orbital biological experiments in and above the Van Allen radiation belts. The extensive ground controls and experimental programs for these flights are now being planned.

"Biotechnology" is concerned with the application of biological and medical research data for the protection and use of human beings in space-exploration systems. For example, figure 2 illustrates the need to study and combine

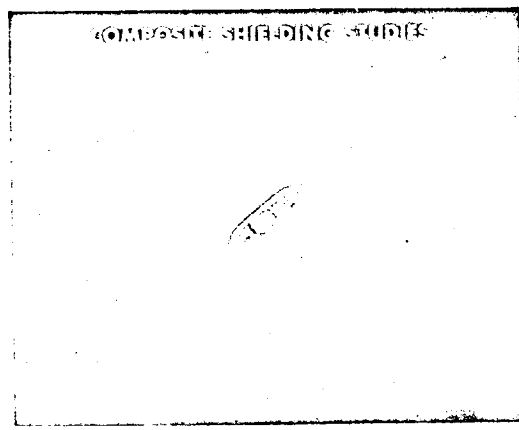

FIGURE 2

various means of protection against radiation, including the potential use of magnetic and electrostatic fields as well as shields made of ordinary materials. One of the major technological objectives of the Mercury program was the development and flight demonstration of the means for supporting human life and performance in space flight. During this program, it was necessary to develop means of measuring and transmitting data relative to the physiological function of both the animals and men being protected by the systems used. Instruments were applied to the remote measurement of heart function, respiration, and temperature. For each step in the program, instrumented animal flights are made to test the effectiveness of the protective systems and to provide new knowledge on the accommodation to environmental changes.

On May 5th, Alan Shepard's flight in the Mercury capsule provided us with the first conclusive proof that, in addition to survival in the weightless flight as indicated by Gagarin, a human being is capable of performing intricate control functions. Shepard was able simultaneously to aline multiple instruments and to provide the manual control coordination necessary to match with the characteristics of his space vehicle. Physiological data recorded during this flight indicated even less variation from normal than did similar measurements taken during the preliminary flight of the chimpanzee, "Ham."

Added orbital flights, first with animals and later with men, are now being planned to explore the effects of longer-term weightlessness and to develop life-support systems adequate for longer-term flight. Chimpanzees have been chosen for these preliminary flights because it has been shown that these animals can be trained to perform intricate tasks. Any degradation of performance provides an extremely sensitive indication of problems in one or more of the body systems. Lower forms of life are carried also for a check on the detail type of malfunction that may have caused a degradation in the performance of the chimpanzee.

Advanced spacecraft developed from these flight tests plus numerous ground-based programs will define the protective systems necessary for more extended exploration by man.

Many of the flights in the near future will be unmanned. Because of the high cost of each flight, it is important that maximum care be taken to get the most possible knowledge from the effort spent. Many of the desired manifestations are not directly accessible to human senses. For example, information is needed to define radiation fields in space, the energy of which we cannot directly see, feel, taste, hear, or smell. Figure 3 illustrates the very tiny portion of the electromagnetic spectrum of energy directly accessible to human vision and the similarly narrow band, in the sound and vibration range, in which we can hear and feel.

To make the best use of man, it is important that the collected information be measured and

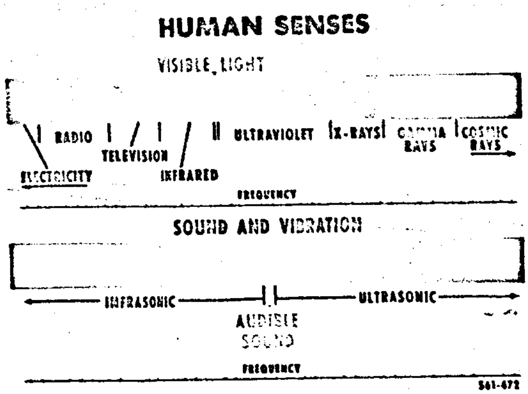

Figure 3

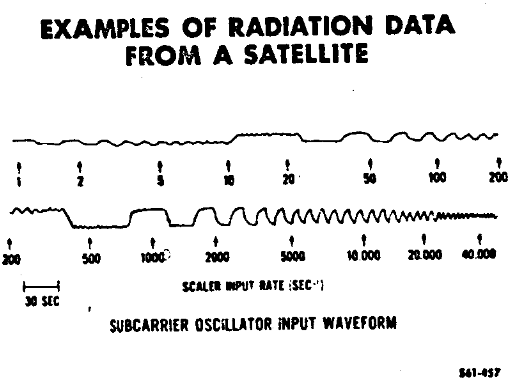

Figure 4

presented in a form that can be easily understood. As an example of this problem, figure 4 is a sample of graphical data received from radiation-measuring equipment aboard a satellite vehicle. It is exceedingly time-consuming and difficult for the best trained scientist to interpret these data. On the other hand, a pictorial presentation of the Van Allen radiation belt, figure 5, conveys a great deal of information on the distribution of these radiations around the Earth to even an untrained individual.

The direct utilization of this type of pictorial information, generated by the use of advanced data-gathering, computing, and display techniques, shows great promise for accelerating the rate at which information can be provided and displayed in a manner conducive to rapid

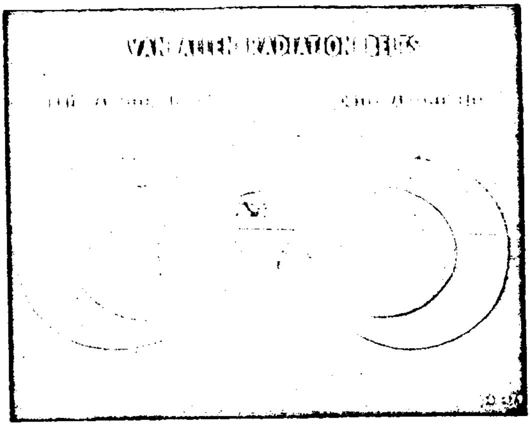

FIGURE 5

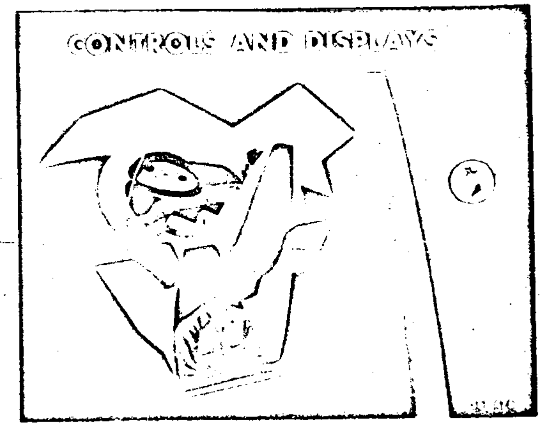

FIGURE 6

assimilation as human knowledge. Figure 6 illustrates a display system in which a man can see directly presented such information as his location, his desired location, and the extent to which he is achieving desired flight objectives. Additional information from sensing instruments can be superimposed to inform him of the degree of hazards such as space radiations or obstacles. The provision of information needed to permit objective selection and to provide the extensive training of the required space-exploration crew members is another important concern in aerospace medicine.

"Space biology" includes the exploration of space for studies of life forms, including the search for extraterrestrial life for knowledge contributing to the understanding of life processes and the evolution of life in our universe.

It is now believed by many that life can and has originated wherever the conditions have been right. University scientists working on this premise have been able to synthesize protein particles from gases typical of some planetary atmospheres. They have found that the size of the particles formed is a function of the gravity force during the experiment. One "g", for example, produces particles about the size of bacteria, but supernormal gravity yields much larger units.

While much of the most important life-detection work must await samples from landing systems or manned landings, preliminary work is under way to include infrared observations of planetary atmospheres for the detection of life-like compounds. Studies are also being made of meteorites for life, or life-like compounds.

Important work is under way also to prevent contamination of the Moon and planets by Earth organisms carried by exploratory vehicles and to provide in turn for the protection of the Earth from the possible danger of rapidly growing extraterrestrial organisms that could conceivably be carried back to Earth by our exploration vehicles.

In summary, an important part of the life-science effort in support of NASA in the exploration of space must be prepared in ground laboratories. It must be clearly understood, however, that the major gains from space exploration will depend on the flight and planetary operations. Accordingly, a manned Earth-orbital laboratory is an important need for further expansion toward true lunar and planetary exploration.

In the process of exploring space, many new techniques and devices are reaching a usable state of development. Their application can provide both new utility and economic progress in such diverse fields as transportation, communication, and education. Already, advanced miniature sensing, analysis, and display devices, stimulated by the biomedical requirements of the space program, are showing potential for direct use by the medical profession to improve the health of people on Earth.

NASA SPACE FLIGHT PROGRAMS

7. NUCLEAR PROPULSION FOR SPACE VEHICLES

by HAROLD B. FINGER*

All of the rocket systems that have been used to date and that are planned to deliver payloads into space in the near future are propelled by engines that utilize the energy developed from the combustion of a chemical fuel with an oxidant. In our most advanced chemical combustion systems, hydrogen will be mixed and burned with oxygen, producing a high-temperature gas jet that is ejected through a jet nozzle, producing the thrust to propel the space vehicle.

Unfortunately, the energy available from the combustion process is limited by the chemical bond energies within the compounds. Therefore, when we talk of conducting deep-space exploration missions or missions requiring expenditure of large amounts of energy, we must search for systems that can provide higher energies in small, compact, lightweight packages. As you might expect, the energy of the atom becomes the leading candidate and, indeed, becomes a requirement to break the barriers to long-range solar-system flights.

Several systems have been proposed for the application of nuclear energy to the propulsion of space vehicles. The two that are receiving emphasis are the nuclear heat-transfer rocket (the Rover system) and the nuclear-electric rocket. Of these two, greatest emphasis is being placed on the nuclear-rocket system. My discussion is concerned with both the nuclear rocket and the nuclear-electric propulsion system being developed for use in our space program.

A drawing of the nuclear-rocket Rover engine is shown in figure 1. Its principal parts are the reactor in which the propellant is heated,

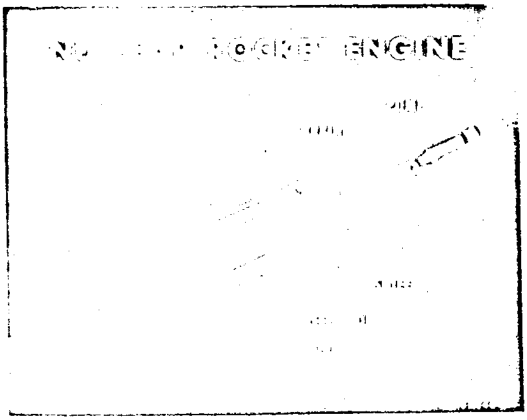

FIGURE 1

the turbopump, the jet nozzle, and the control system, which is not shown here. Hydrogen is pumped from the propellant tank to the jet nozzle, where it is used to cool the walls of the jet nozzle. The hydrogen is stored as a liquid in the propellant tank and is at a temperature of approximately −420° F at the entrance to the double-walled jet nozzle. After cooling the jet-nozzle walls, the hydrogen cools the reflector of the reactor. The reflector portion of the reactor is used to conserve the neutrons that are required to produce the fission process. The reflector, therefore, helps to reduce the size of the reactor core and the amount of uranium that is required in the reactor. The hydrogen then passes through the reactor core, where it comes in contact with fuel elements that are loaded with the uranium fuel. The capture of neutrons by the uranium causes fission of the uranium nucleus, releasing the large fission heat energy. This fission heat energy is transferred to the hydrogen flowing through the reactor

*Manager, AEC–NASA Space Nuclear Propulsion Office, and Assistant Director for Nuclear Applications, National Aeronautics and Space Administration.

past the fuel element. After being heated in the reactor, the hot hydrogen gas is then accelerated through the jet nozzle, producing thrust.

Hydrogen is used in our system because it produces a high specific impulse, which means a high thrust for every pound of propellant that flows through the jet nozzle in a second. The specific impulses that we believe are attainable in the solid-fuel-element nuclear rocket are two to three times the values that are possible with the chemical combustion engine systems. This increase in thrust for every pound of propellant flow gives a substantial reduction in the total weight of propellant that is required to perform a specific space mission. As a result, larger payloads can be delivered on long-range missions than would be possible with chemical combustion systems. The more difficult the mission, the larger is the payload advantage of the nuclear rocket over the chemical rocket.

As a result, the true potential of the nuclear rocket shows up to greatest advantage on distant and difficult missions such as the one shown in figure 2. This figure shows a comparison of

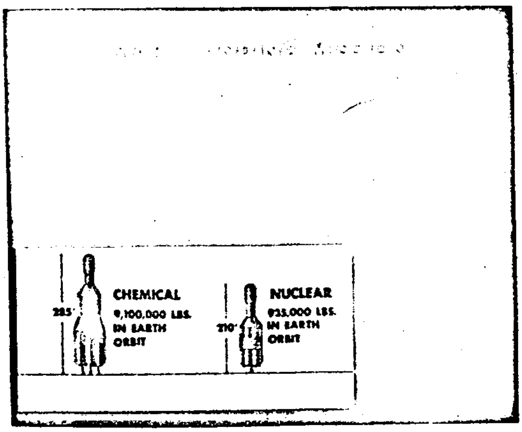

FIGURE 2

nuclear and chemical vehicles that would be required to perform a manned Mars exploration. I believe it is clear that, if such a mission is to be done, nuclear energy will be required. Obviously, any such analysis must be considered as extremely preliminary and must be based on many assumptions regarding the space environment, man's adaptability in space, and the requirements of long-distance space flight. In these calculations, it is assumed that the space vehicles shown here have been assembled in an Earth orbit. These calculations assume that the total trip time, including a 40-day wait period, is 1 year. You can see that the all-chemical vehicle using hydrogen and oxygen as propellants would have an initial weight in Earth orbit of almost 10 million pounds in order to perform this mission. The nuclear vehicle would weigh $\frac{1}{10}$ the weight of the chemical vehicle. The reactor powers required in the nuclear vehicle are in the neighborhood of 10,000 megawatts in the first stage, 6,000 in the second, and 1800 megawatts in the third stage.

In addition to the advantages for such long-range planetary missions, the development and application of nuclear stages to vehicles to be used for advanced manned lunar-traffic operations would offer performance and economic advantages. The power levels that will be required in the planetary vehicles will be suitable for use in such manned lunar operations.

The development of the technology of the nuclear rocket is already under way in the joint AEC–NASA Rover program. As part of this program, we will be developing reactors that can operate at temperatures above 3500° F with hydrogen as a propellant for the full-power duration that will be required for all of these lunar and planetary missions. Work is also in progress on the development of all of the other principal components of nuclear-rocket-engine systems such as the pumps, nozzles, controls, and shields that are required. Our program will therefore provide all of the nuclear-propulsion technology required for extensive space operations.

The major early steps in the program were taken when three research reactors named KIWI, after the flightless New Zealand bird, were tested in the summer of 1959 and the summer and fall of 1960 by the Los Alamos Scientific Laboratory. These reactors were called the KIWI–A, the KIWI–A′, and the KIWI–A3. The first reactor tested in July 1959, the KIWI-A, used a flat-plate graphite fuel element such as this sample fuel element.

A drawing of the arrangement of these fuel elements in the KIWI–A reactor core is shown

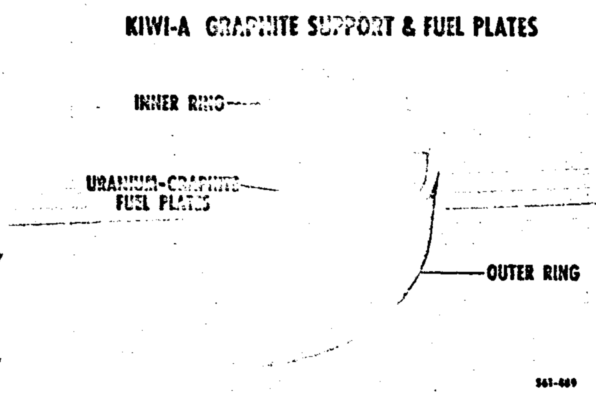

FIGURE 3

in figure 3. The fuel-element plates were inserted into the unloaded graphite support structure. The ribs on each plate were 0.050 inch high and acted as spacers between two adjacent plates. The hydrogen gas used in the test passed through the 0.050-inch space and was heated as it flowed through the reactor. Each of these plates was ¼ inch thick and was loaded with U^{235}. A heavy-water (D_2O) island was located within the inner ring of this wheel-like support structure. The control rods required to regulate the fission rate, and therefore the power of the reactor, were located in the central heavy-water island.

A photograph of the KIWI-A′ reactor, the second reactor, taken during its full-power test in July 1960, is shown in figure 4. The external appearance of all three of the reactors tested to date was purposely made essentially the same as the one shown here. Hydrogen gas rather than liquid hydrogen was used as the propellant in these first tests. In addition, water rather than hydrogen was used to cool the jet nozzle and the pressure shell. As you

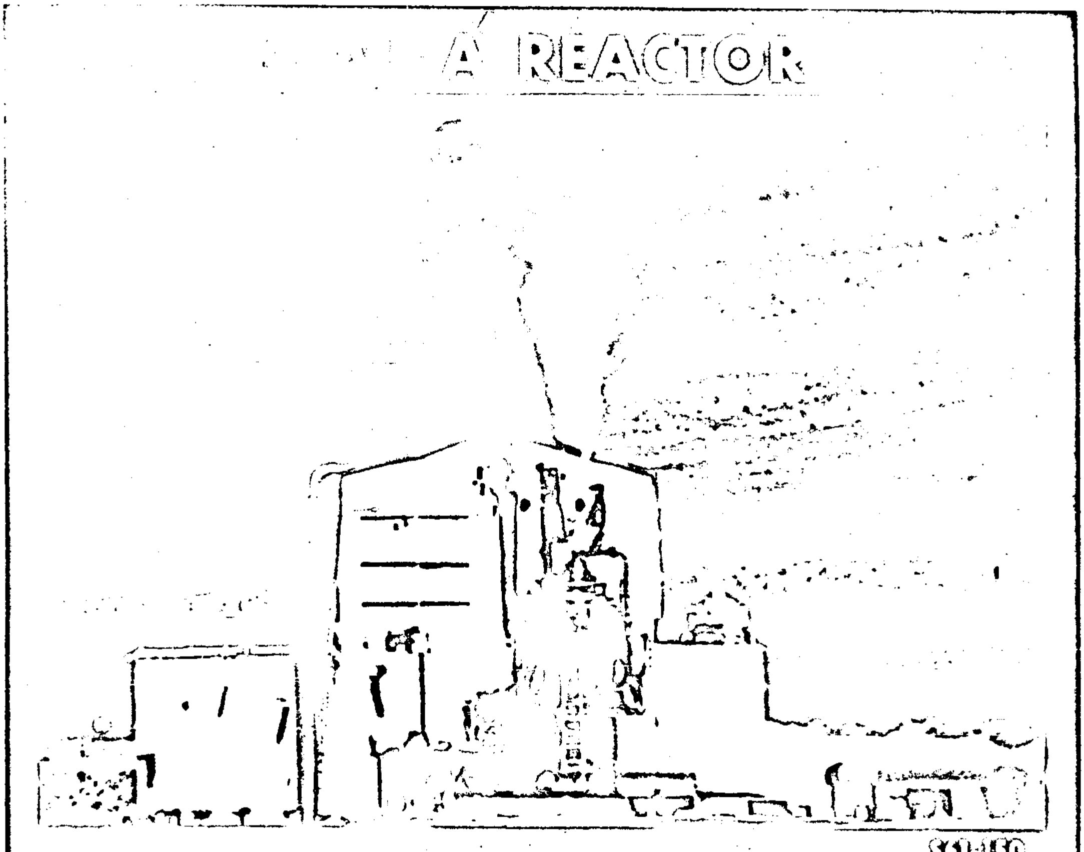

FIGURE 4

can see, the jet was directed upward in these tests. All of these special features were utilized in order to simplify the operations of these early research tests.

Although the external appearance of the three reactor tests was the same, the second and third tests, this KIWI-A′ and the KIWI-A3, used a reactor-core geometry different from the one used in the KIWI-A reactor that I described earlier. The results of all of these tests were extremely encouraging in helping us evaluate the materials used, the design procedures used, and in giving us confidence as to our understanding of the conditions in these high-temperature systems.

As a result of the information gained in these early tests, we consider that we are ready to take on the next test series, the KIWI-B series. The KIWI-B test series will start later this year and will include tests using liquid hydrogen as a propellant. This series of tests will evaluate the performance of several different reactor designs. The use of liquid hydrogen in the KIWI-B tests will provide us with important information in an area that is not yet well evaluated. The effects of liquid hydrogen as a propellant have been analyzed, as well as is now possible, with reassuring results. However, the actual operation, control, and startup of a reactor using liquid hydrogen are major milestones in our program.

The testing of a reactor with liquid hydrogen requires that we develop certain components similar to the nonnuclear components that will eventually be required in the nuclear-rocket engine. Some of these are shown in figure 5.

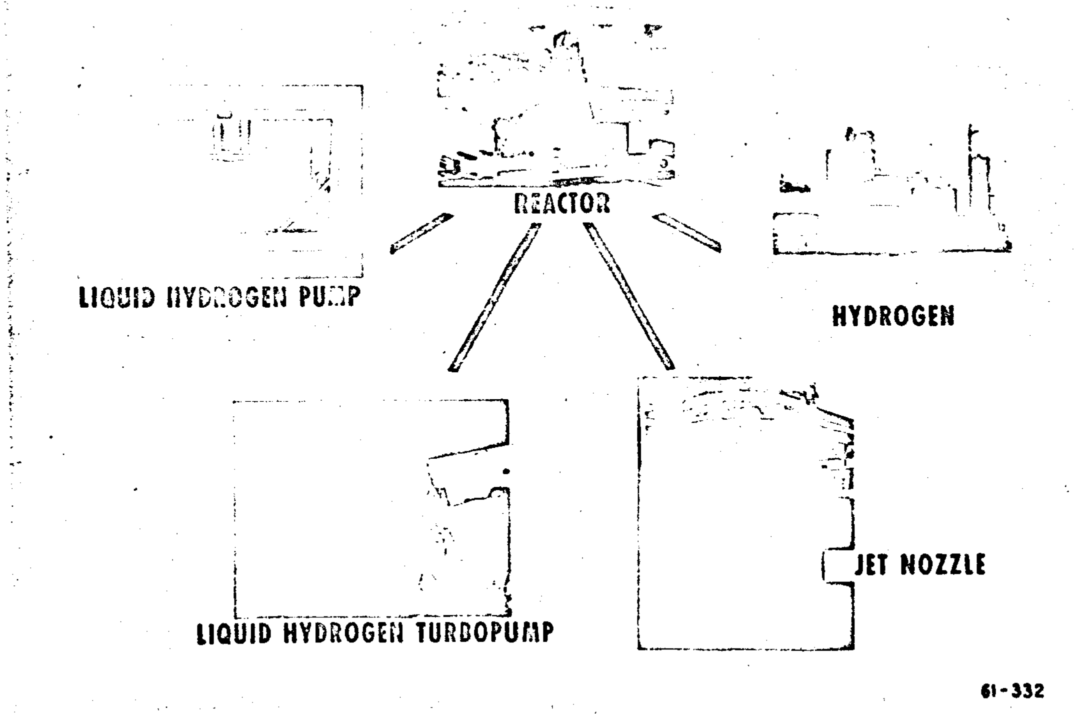

FIGURE 5

It is obviously necessary for reactor testing with liquid hydrogen to pump the hydrogen from the storage tank into the reactor. Two turbopump systems are now under development to provide such a capability. The first of these is the pump system shown at the left of figure 5. This is actually the system that has been used to develop our liquid-hydrogen pump. The pump is driven by a turbine from the Atlas rocket engine. When this turbopump system is installed in our first liquid-hydrogen test facility at the AEC Nevada Test Site, cold hydrogen gas will be used to drive the turbine much as steam drives our ground powerplant turbines.

The turbopump shown at the lower left is now under development. It begins to look more like the flight-type turbopump of the nuclear-rocket engine shown in figure 1. The space between the turbine located at the bottom of this support structure and the pump at the top of the structure is occupied by a meter to measure the torque imposed by the turbine on the pump shaft. It is used only as a means of measuring pump and turbine performance and will be removed before installation in our second liquid-hydrogen reactor test facility, which is now under construction at the Nevada Test Site. In our reactor tests, this turbine will be driven by the hot combustion products of hydrogen and oxygen burned in a gas generator. It could also be driven by hot hydrogen gas; and in a flight engine, hot hydrogen would probably be the driving gas.

During the next KIWI-B series of tests, another advance will be made. A hydrogen-cooled jet nozzle will be used in place of the water-cooled nozzle utilized in the KIWI-A tests. The high heat flow from the hot hydrogen jet to the jet-nozzle walls requires that we use liquid hydrogen as a coolant. Water would be completely unsuitable. I should point out that this nozzle-cooling problem is another of our unanswered questions. Even the hydrogen-oxygen chemical combustion engines do not give as high a heat flow into the nozzle wall as does the nuclear-rocket engine. We do not yet have sufficient data to be sure that our analytical design techniques are accurate. As an insurance precaution, therefore, we are also doing work on a nozzle just like this one but with a ceramic coating on the inside surface to act as an insulator to keep the heat flow into the nozzle wall low. We are now evaluating such ceramic coatings.

At the right of figure 5 is shown a photograph of the Linde liquid-hydrogen plant that is providing much of our liquid hydrogen for this program. The demands on liquid hydrogen have, however, grown so rapidly that another plant is now being built, and the prospects are good that still another will be required before very long.

In essence, I believe that you can see that the KIWI-B series of tests, including a reactor, a liquid-hydrogen turbopump feed system, a liquid-hydrogen-cooled jet nozzle, and, of course, automatic controls, constitute what might be called a "breadboard" engine. A breadboard engine is one that contains all of the important parts of the engine, but these parts are not necessarily flight-weight parts nor are they positioned as they would be in a real engine. We intend that the KIWI-B series of tests should lead to a reactor that can be flight-tested at an early date.

Four parallel industrial studies have been conducted to evaluate the various methods that are available for flight-testing the first nuclear-rocket propulsion system. In general, all of the four contractors suggested a flight test similar to the one shown in figure 6. Both NASA and the AEC agree that flight-testing of this new and advanced system is necessary to provide design information and also to provide

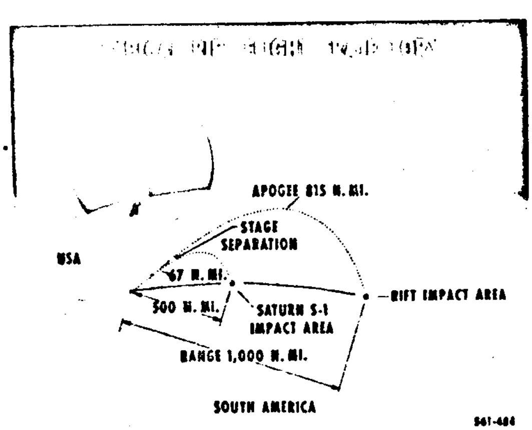

Figure 6

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confidence in the solution of any unexpected problems that may be the result of the space-flight environment.

In this flight-test system, the nuclear test stage would be launched by the first stage of the Saturn vehicle (the S–I stage) on a ballistic lob trajectory entirely over water. The range of the flight would be carefully controlled so that the impact point would be accurately predicted. The nuclear stage would be started at altitude, as would be the case in an operational mission. The possible hazard at the launch site is therefore minimized. It is important to note that continued development of such a flight-test system could lead to an operational third stage on the Saturn vehicle. The application of such a nuclear third stage could increase the escape payload of the Saturn vehicle by 2 to 3 times the value of the all-chemical Saturn system. The conduct of a flight test in this manner will therefore provide useful technical information applicable to a Saturn nuclear stage and to nuclear technology generally. If we are first in such a flight, it will also undoubtedly provide a boost to our technological stature. Our program planning indicates that it is reasonable to expect that such a flight can be conducted in the 1966 to 1967 time period.

We are now in the process of selecting an industrial contractor who will be assigned responsibility for the development of the NERVA engine, our first *N*uclear *E*ngine for *R*ocket *V*ehicle *A*pplication. This NERVA engine will be utilized in our flight-test system. It will be developed at the Nevada Test Site in facilities that will include test stands such as the Test Cell D, which is now under design. A drawing of the present concept of the Test Cell D complex is shown in figure 7. The vertical stand will, for the first time, permit reactor systems to be fired downward. Hydrogen storage is shown by the large vacuum-jacketed spheres. The control center as visualized in this drawing is underground approximately 1000 feet from the test stand. During test operations on the engine, shielding will be moved up to enclose the engine, reducing the direct radiation to the test stand and avoiding long-lived activation difficulties. Design work is now in process on a master plan of the overall facility complex

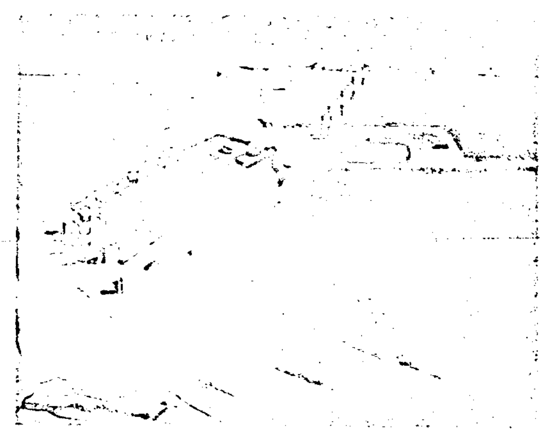

FIGURE 7

that will be required to develop nuclear-rocket systems including the engines and the vehicles.

In general, our program aimed at the development of nuclear-rocket technology recognizes the long-term applicability and utility of nuclear-propulsion systems. We recognize that, the sooner the technology is developed and demonstrated, the sooner it will be used to great advantage. We recognize further that the long-range missions through the solar system require the use of such propulsion systems. We must therefore conduct this program on an urgent basis.

The second major nuclear system that I would like to discuss is the system to generate electrical power for application in the advanced electric-propulsion concepts that are being studied by many different industrial and Government groups. In this system, electrical power is used to accelerate charged particles to high velocities and high specific impulse, producing the thrust to propel space vehicles.

One of these concepts is shown schematically in figure 8. This is a sketch of the principal elements of an ion accelerator system. Ions of a heavy element such as cesium are produced when the cesium vapor is brought into contact with the heated porous-tungsten grid. Essentially, this heating of the cesium strips electrons from the cesium atom and leaves a positively charged atom, which is referred to as an ion. These ions are then accelerated through a voltage difference, providing a high-velocity

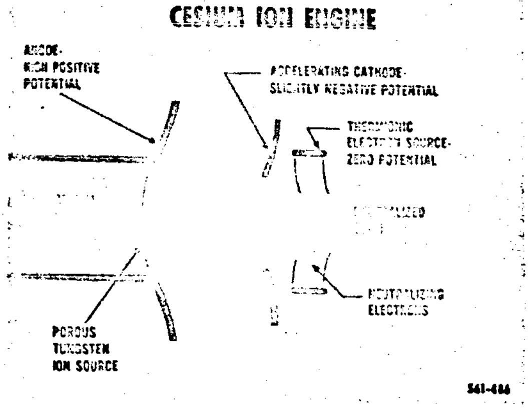

FIGURE 8

but low-thrust jet. Because like charges repel each other, the accumulation of positive ions at the discharge of the electric jet would exert a force tending to slow down the flow of other positive ions out through the electric jet. In order to avoid the buildup of positive charge in this discharge region of the jet, electrons are injected into the stream, thereby neutralizing the charge in this area and relieving the obstruction to further higher-velocity flow. Figure 9 shows a photograph of an ion jet engine operating in a vacuum chamber at the Lewis Research Center. The source of cesium ions and the accelerator grid and the electron guns are shown.

A true evaluation of the feasibility of this type of accelerator system will require space

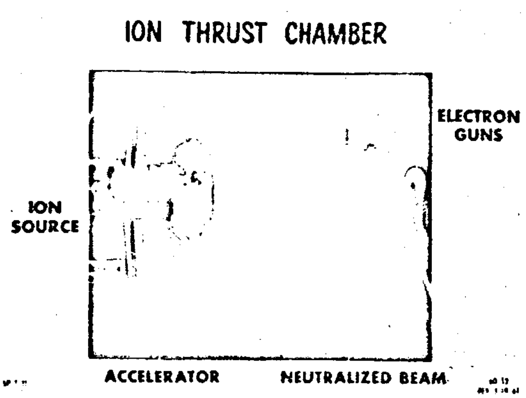

FIGURE 9

experiments, since no ground test facility can truly simulate the infinite expanse and the hard vacuum of space. We plan to conduct such space feasibility experiments on the Scout solid-propellant vehicle in 1962 using batteries as the electric power supply to provide the voltage difference required to accelerate the ions.

It is important to point out that the thrust produced in these electric-propulsion systems is extremely low compared to the weight of engine and the rocket it propels. For this reason, electric-propulsion systems cannot be used in booster or launch-vehicle applications. They can, however, be used once the spacecraft has been placed in orbit, when it is no longer necessary that the engine be capable of lifting the spacecraft weight. In this application, the low thrust is exerted over a long period of time until the velocity required to reach the desired space target is attained.

The conduct of space missions using electric propulsion requires the development of systems capable of generating large amounts of electrical power in small, lightweight, long-life packages. Batteries and the solar cells that have been used so effectively to supply the auxiliary power requirements of our satellite experiments to date are far too heavy for this electric-propulsion application. Solar-collector systems would also be too heavy. Only nuclear-reactor energy sources combined with turbogenerator or static systems that convert the heat energy of the reactor to electrical power output offer the potential performance required. However, even these nuclear systems require that extensive research work be conducted before systems can be developed that are capable of performing the long-range space missions for which nuclear energy is desired.

The potential performance of nuclear-electric rockets is demonstrated by the results of the mission calculation shown in figure 10. We have assumed that nuclear-electric power-generating systems having powers of 1 and 10 electrical megawatts (1000 and 10,000 ekw) with specific powerplant weights of 10 and 1 pound of engine weight per electrical kilowatt, respectively, are used to propel space vehicles electrically from an Earth orbit to a capture at the planet Saturn. In this case, the elec-

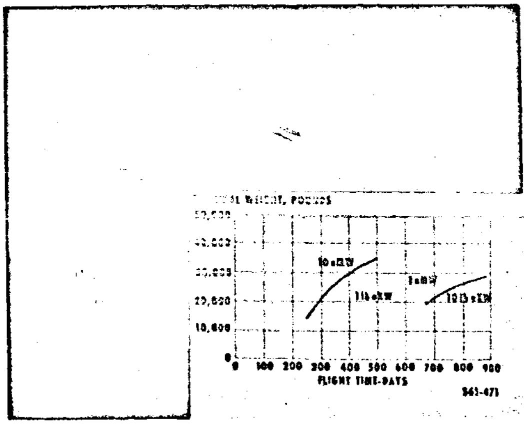

FIGURE 10

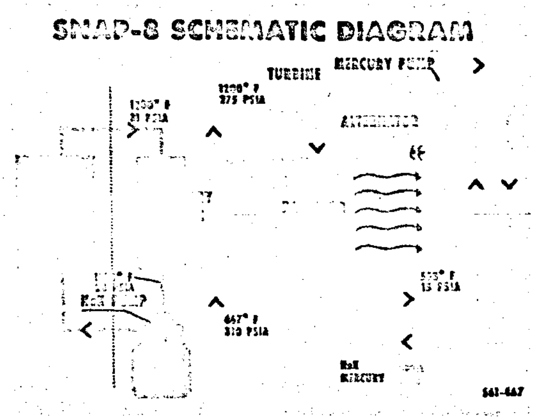

FIGURE 11

trically propelled spacecraft is considered to be placed in an Earth orbit by the Saturn vehicle. The total weight delivered to the planet Saturn is the same for the two powerplants; however, the flight time is considerably reduced with the high-power, low-specific-weight system because of the higher thrust and the higher initial acceleration possible with this system. Approximately two-thirds of the orbital spacecraft weight, or 30,000 pounds, can be delivered to Saturn. Of this total weight, 10,000 pounds is taken up by the weight of the electric-propulsion system. It is important to recognize, however, that for such distant missions a portion (and possibly a large portion) of this powerplant weight is useful payload, in that it can be used to provide the electric power to collect and transmit necessary data back to the Earth in addition to providing propulsive power.

The technology used in this analysis is well beyond our present capability. Indeed, at this time, we are not at all sure that we can achieve the specific weights of 10 and 1 pound of engine per electrical kilowatt that were assumed in this analysis. It is for this reason that we are starting our electric-propulsion program closer to available technology and, at the same time, conducting the necessary fundamental and applied research work required to permit the design and the development of high-power systems. Our first nuclear-electrical power-generating system development suitable for electric propulsion is therefore our 30- to 60-kilowatt SNAP-8 program. This program is being supported jointly by the NASA and the AEC. As is the case for the Rover program, the AEC is responsible for the development of the reactor and reactor controls, while the NASA is responsible for the development of all of the nonnuclear portions of the system and for the integration of the reactor and the nonnuclear components into an operational and reliable electric-power-generating system capable of meeting all of the NASA requirements.

A schematic drawing of the SNAP-8 system is shown in figure 11. In this system, an alloy of sodium and potassium generally referred to as NaK is heated to approximately 1300° or 1350° F in a compact nuclear reactor. The reactor in this system is only 15 inches in diameter. The heated NaK is then passed through a boiler, where its heat boils the mercury working fluid in the secondary loop. The mercury vapor then drives the turbine much as steam drives the turbines in our ground electric-power plants. On the same shaft as the turbine are the generator, which generates the electric power output, and the pump that forces the mercury to flow through the boiler and around the secondary loop. Part of the electric power produced by the generator is supplied to a small electric motor that drives the sodium-potassium pump; the remaining electric power will be supplied to the electrical thrust accelerator (e.g., to an ion engine) and to any communication system that is required. After leaving the turbine, the mercury working fluid passes through a condensing radiator where it is condensed back to a liquid so that it may start the cycle over again. In this SNAP–8 system, the radiator will have an area of approximately 500 square feet at the 60-kilowatt power rating. The radiator will be so large that it will have to be folded up to be packaged into the nose-cone of our vehicles; and then, when it is in orbit, it will be erected, giving a flat, two-sided radiator configuration. The specific weight of this system will be 50 pounds per electrical kilowatt, much higher than the 1- to 10-pound values mentioned earlier.

Most of the components of this system are now under test. The reactor used in this program uses the technology that is being developed for the AEC in the SNAP–2 program. Data are now being obtained on the fuel elements that will be required to provide the higher power output of this SNAP–8 system. Experimental work is in process on the boiler, the generator, the turbine, and the pumps of this system. A sample pump test loop is shown in figure 12. The sodium-potassium pump is

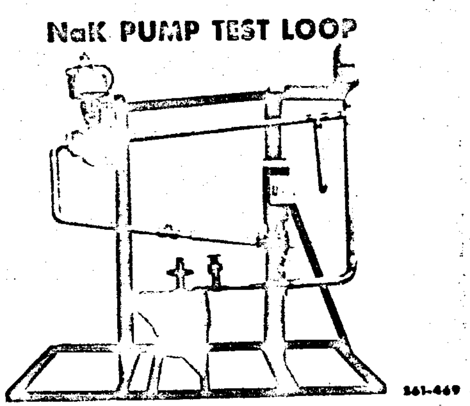

FIGURE 12

driven by an electric motor, as is the case in the final SNAP–8 system. The valve, the purification system, and the expansion tank that are required to operate liquid-metal flow components successfully are shown. Because the SNAP–8 system must eventually be capable of operating continuously and unattended in space for at least a year and as long beyond that as possible, many long-duration tests in such test loops will be required to ensure that each component is highly reliable before it is combined with the other components of the system in the conduct of the necessary full system development tests.

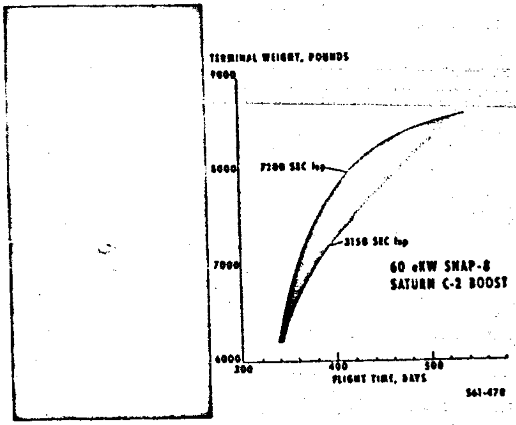

FIGURE 13

Although the SNAP–8 system is low in power compared with the powers that will ultimately be required and is high in specific weight compared with what has been shown on the Saturn mission chart, it will have some interesting electric-propulsion capability. Figure 13 shows the payload that can be delivered by a spacecraft propelled by a SNAP–8 ion-propulsion system on a mission flying by Jupiter. In this case, the SNAP–8 spacecraft is launched by the Saturn vehicle. This analysis shows the variation of the payload with the flight time required to arrive at the planet Jupiter for specific-impulse values of the electrical system between 3200 and 7200 seconds. These values of payload are very respectable values and indicate that propulsion for such a Jupiter mission may be available in this decade.

I indicated earlier, however, that we want ultimately to develop systems of much higher power (I mentioned 1 and 10 electrical megawatts) with much lower specific engine weights than are possible with the SNAP–8 technology. In order to achieve such low specific weights, it is necessary that we develop systems that will operate at much higher temperatures than the SNAP–8 system. Only by going to higher temperatures can we keep the size of the radiator sufficiently small to permit the attainment of low weight. Mercury is unsuitable for high-temperature operation, just as water is unsuitable for operation at the temperatures of the SNAP-8 system. It boils at too low a temperature when operating at reasonable pressures. Other working fluids are required. Although high pressures are possible, they require heavy piping throughout the system and in general increase the weight, the complexity, and the structural requirements of the system. It is therefore necessary that we use high-boiling-point liquid metals such as rubidium, potassium, or sodium in our advanced systems. It is possible to boil such metals and use them as working fluids in turbogenerator systems.

Some of the problems that we face in the development of these systems are associated with the corrosion of the piping that occurs with these fluids at high temperatures. The results of a simple test in which mercury was boiled in a test capsule are shown in figure 14. This capsule was made of a material called Haynes Stellite 25, which is a stainless-steel alloy using high cobalt and low nickel content. You can see the corrosion of the capsule material that resulted in the region of the boiling interface. This test was run for only 1000 hours at a boiling temperature of 1100° F. Materials must be developed to permit the successful operation of these systems at the temperatures of interest for the many thousands of hours (over 10,000 hr) that are required.

As was pointed out earlier by Mr. Ames, another problem that we face is the strong possibility that meteoroids in space will puncture the large, football-field-size radiator. Mr. Ames has indicated our ground laboratory work to help us understand this problem. In addition to those laboratory tests, space-flight tests are required. Our first space experiment aimed at evaluating the penetration of structural material by meteoroids is shown in figure 15. This experiment is the result of work of the Langley, Lewis, and Goddard Centers. The experiment will be launched in the near future on a Scout vehicle. In one section of the payload, we have gas-pressurized cans, which are so instrumented as to indicate the occurrence of a pentration. In another one, a break in metallic foil will indicate a puncture; and in the lower set of instrumentation, the occurrence of a tear in a wire that is wound on a strip of plastic will indicate a puncture. Much more data are required on this phenomenon. Plans are now being generated for other such space experiments in which the surface area sampled is considerably larger and is more representative of the conditions that will exist in our electric-power-generating system.

In addition to these problems, we also must face the unknown effects of zerogravity on the boiling and condensing of fluids. We have learned to understand these physical conditions here on Earth where gravity plays an important part. We do not know what the differences will be in space. Space rocket experiments are now being conducted to determine the effects of zerogravity on the hydrogen in hydrogen

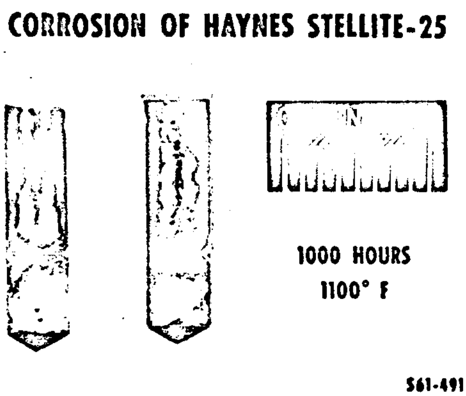

FIGURE 14

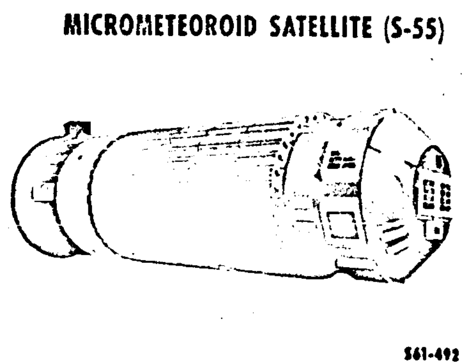

FIGURE 15

tanks, and plans are being made to evaluate the effects on boiling and condensing of liquid metals. The limited amount of data obtained to date in short-duration zerogravity aircraft flights have been informative, but our information is not adequate for design purposes.

Much remains to be done in the development of these nuclear-electric-propulsion systems. The practical feasibility of these systems is yet to be demonstrated. Flight tests will be required for such feasibility demonstrations because of the important effects of the space environment on the satisfactory operation of the system.

In conclusion, I must repeat that nuclear systems are required to perform long-range space missions requiring high payloads. They will provide us with a capability to travel freely in space. Only nuclear energy offers us such a long-term usefulness. I believe that the nuclear rocket will find a solid place in our space program during this decade because of its ability to perform extensive lunar and planetary missions. Our program is so directed. Although early electric-propulsion systems will be developed and may be used during this decade, the high-power systems discussed will probably not be available or, for that matter, required until after 1970 to perform missions to the planets beyond Mars and Venus. Nuclear-energy propulsion for space missions must be urgently developed as an important part of our national space program.

NASA SPACE FLIGHT PROGRAMS

8. LAUNCH-VEHICLE PROGRAMS

by Wernher von Braun*

As you all know so well, thanks to Alan Shepard's flight into space the other day, the United States is now back in the solar ball park. We may not be leading the league, but at least we're out of the cellar. We have the players and the coaches. And in today's crucial interplanetary series, the next thing we need is to put an American around the Earth, hit a two-bagger to the Moon, and then make a home run around Mars.

Even today, a lot of people still ask me, "Why do you want to go to the Moon?" I like to remind them of what Dr. Edward Teller once said: One of the main things that Christopher Columbus hoped to do was to improve trade relations with China. He didn't succeed—even to this day—but look at the byproducts.

Let me say at the outset that this country has nothing to be ashamed of in comparison with the Soviets in space exploration to date. This comparison may have been valid 3 years ago, but today we have orbited many more scientific satellites than they; and from them we have gleaned a great deal more new scientific information from the universe than anyone else.

The area where we are obviously behind is in the field of big boosters, the big push. That is the bottleneck. That's why I should like to talk with you about our efforts in big-booster development. I shall discuss three in particular: Centaur, Saturn, and Nova.

But, before I go into that, let me say that we're all highly gratified, of course, at Alan Shepard's successful and historic voyage aboard the Mercury-Redstone rocket. But to achieve this we had to fall back on that old reliable Redstone rocket (fig. 1). The Redstone, taking off on the left, was first developed as a weapon. It has never yet been fired in anger. But when we got into trouble (and maybe angry) because the Russians beat us up there with the Sputniks, we had to call on the Redstone to put the first American Earth satellites into orbit. In the middle is the Jupiter C, which lofted Explorer satellites I, III, and IV. Then after Yuri Gagarin's orbit—in an effort to stay in the man-in-space race—we again relied on that old reliable Redstone to boost our first American into space. You see it on the right with the space capsule on top. Following the Mercury-Redstone will be the Mercury-Atlas, which will place an American in orbit later this year.

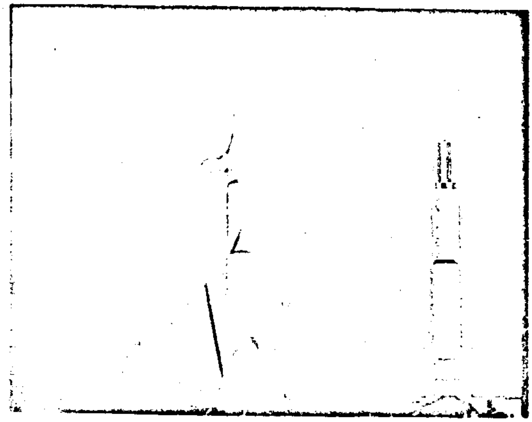

Figure 1

Already, mankind as a whole can be proud of these first physical dents into the cosmos. And man can look forward with the fullest confidence to many more space feats that will not only enrich his store of knowledge, but without question will help him to live happier

*Director, George C. Marshall Space Flight Center, National Aeronautics and Space Administration.

and longer, and maybe even teach him how to behave a little better.

Well, as to How and When, to put it simply, the United States now has a whole stable full of other good rockets to do the job with; and from all indications we're now going to accelerate our most vital space-exploration programs and timetables rapidly and forcefully. Today I should like to talk with you about three big space-exploration vehicles.

First is the Centaur (fig. 2). The Centaur is being developed as the first high-energy space

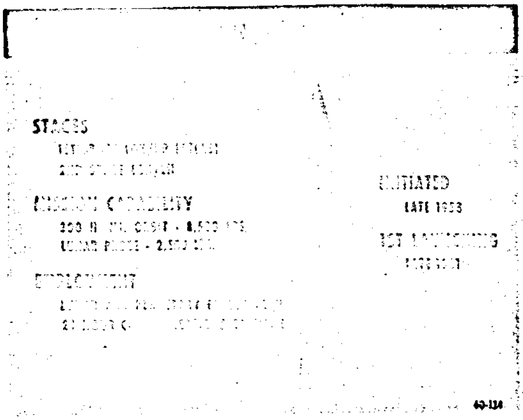

FIGURE 2

vehicle. It is the first step forward in advanced liquid propellants. With the Centaur, we hope to open the entire inner solar system to peaceful research. It is a two-stage rocket with a modified Atlas for a first stage. Three main rocket engines in this stage generate 360,000 pounds of thrust. The second-stage Centaur is powered by two hydrogen-oxygen engines of 15,000 pounds thrust each.

The Centaur is scheduled to begin flight tests soon. It will be used to launch interplanetary probes that are planned for next year, and for soft landings on the Moon in 1963.

Here in the service structure is the fully assembled Centaur (fig. 3). It stands 105 feet high and is 10 feet in diameter. Both stages are built of thin-gage, lightweight stainless steel. Each stage is free of internal framework and is pressurized to maintain its shape.

The Centaur second stage is shown in figure 4 in the Convair Astronautics factory in San

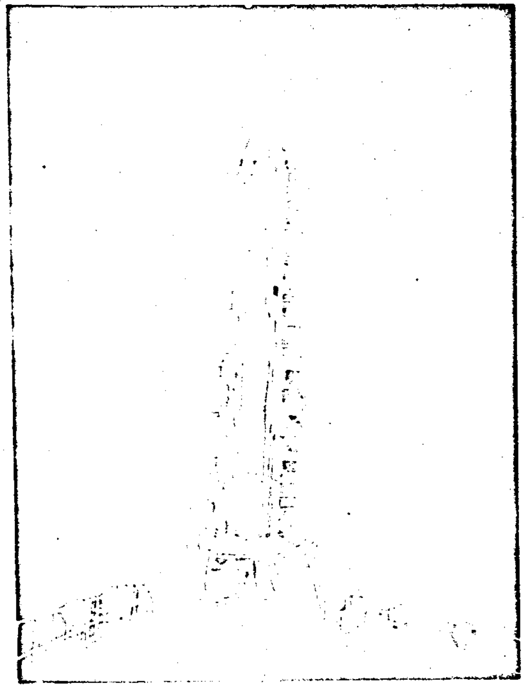

FIGURE 3

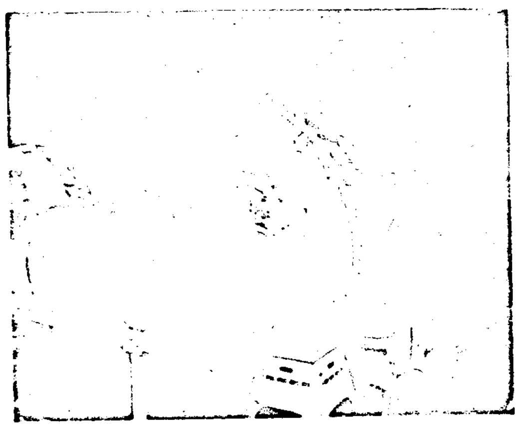

FIGURE 4

Diego. In the background you can see the Atlas booster.

The high-energy hydrogen engines of the Centaur second stage, shown with covers on here, are under development by Pratt & Whitney of United Aircraft at West Palm Beach, Florida.

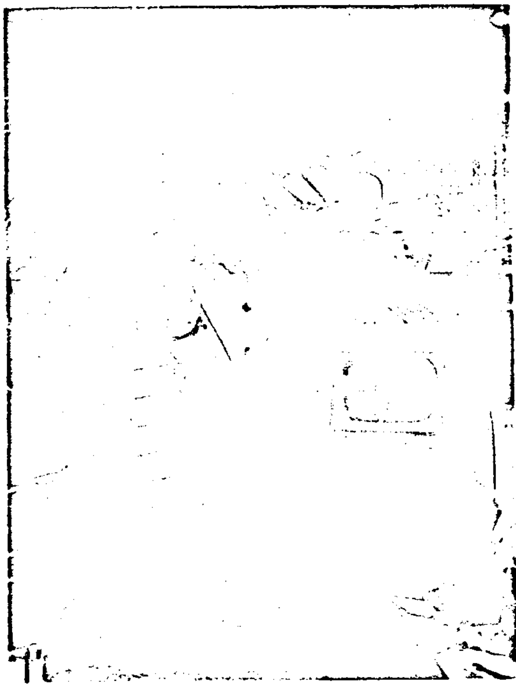

FIGURE 5

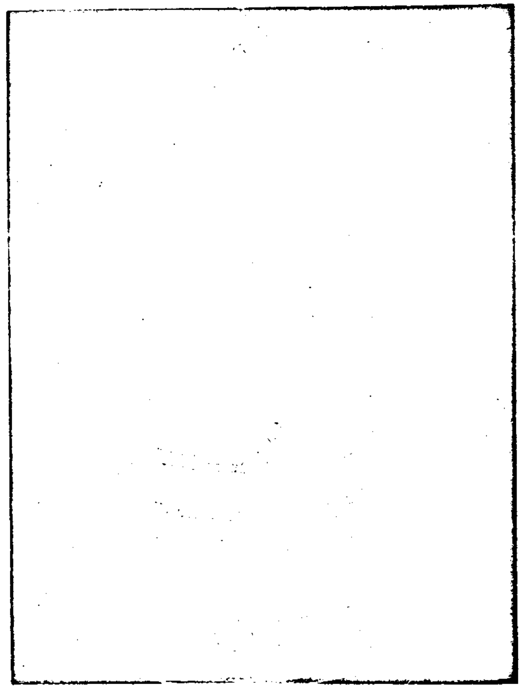

FIGURE 6

Because liquid hydrogen offers a maximum amount of energy per pound, it becomes possible to lift payloads with a two-stage vehicle that would require three or more stages using more conventional fuels. Centaur's hydrogen-oxygen engines will produce 40 percent greater performance than today's rocket engines that burn kerosene-type fuels.

Joining the second stage to the first is more than just bolting a couple of tanks together. In figure 5 you see the complexity involved in hooking together the many electronic, hydraulic, and pneumatic connections that make the whole bird come alive. The hooking-up operation on the ground isn't so bad. The hard part comes when, way out there in space, you have to yank everything apart in a split second with explosive bolts.

Here is a beautiful picture against red velvet of a hydrogen engine (fig. 6). This is the way it is supposed to look, before and after tests.

This is research. This is the way we learn. In figure 7 you see two engines following what I would call an unsuccessful test. If you look

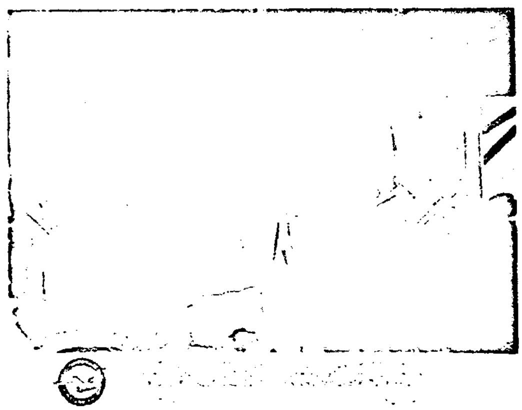

FIGURE 7

hard, over on the right you can see which engine came off second best. But in exploring the unknown, you naturally can't always predict what will happen. Neither, in a research and development program, can you always stick to schedules; because when an accident like this one hits you, you can't run another test the next day.

And now for Saturn. Thanks to a little clever faking—and with the cooperation of the good people of Tulsa—we see the Saturn deep-space rocket right in the middle of Boston Avenue here in your fair city (not shown). This picture was made, looking north, from just about in front of your Chamber of Commerce, the cosponsor of this space conference.

This particular Saturn stands about 18 stories high. Back in the rear I see the 20-story First National Bank Building. The Saturn rocket not only compares in size with the bank, but I suspect a financial comparison might also be made.

With the help of private industry and universities around the country, the Saturn space carrier vehicle is under development by the NASA George C. Marshall Space Flight Center at Huntsville, Alabama.

Several versions of the Saturn are being considered. Even the smallest is the world's largest known rocket.

Here is a cutaway of the Saturn booster showing the fuel and oxygen tanks (fig. 8). There are eight tanks 70 inches in diameter surrounding one tank in the middle of the cluster that is 105 inches in diameter. Four of the outer tanks, and the middle tank, hold liquid oxygen. The remaining carry the kerosene.

You can't see them all here, but the booster has eight Rocketdyne kerosene-oxygen engines, each of which develops 188,000 pounds of thrust.

The Saturn represents a fourfold jump in thrust power, from the 360,000-pound-thrust Atlas to the 1.5-million-pound-thrust Saturn. This is equal to the energy developed by almost all of the 165,000 automobiles in Tulsa County.

This particular first stage will be used to boost the first two versions of the Saturn rocket now under consideration into space.

For our purposes, we call the three versions of Saturn C–1, C–2, and C–3.

Here is the second stage of the first, or C–1, version of Saturn (fig. 9). This stage will be powered by six hydrogen-oxygen engines, each developing 15,000 pounds of thrust. It is some 17 feet in diameter and about 40 feet tall. This

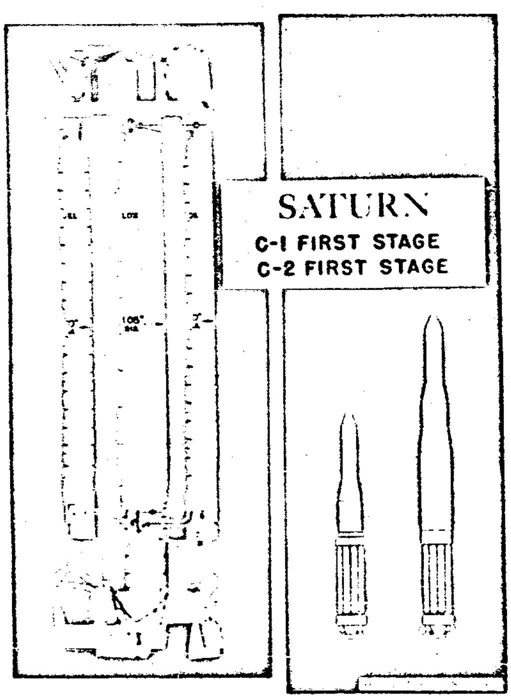

FIGURE 8

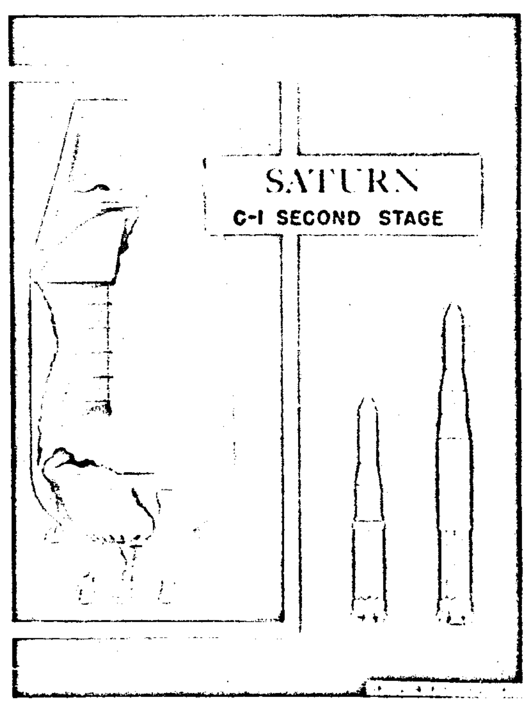

FIGURE 9

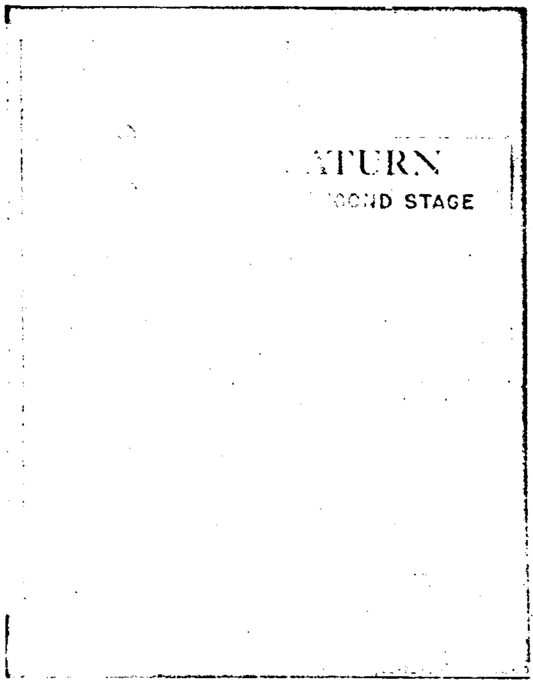

Figure 10

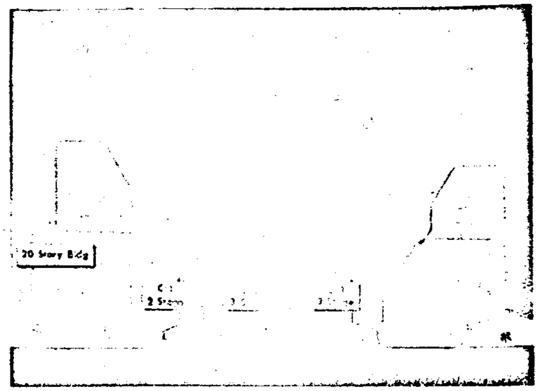

Figure 11

stage is now under development by Douglas Aircraft Company of Santa Monica, California. It will also serve as the third stage of the second, or C–2, Saturn rocket.

A new development in liquid-rocket engines is under way to power this, the number two stage, of the second, or C–2, Saturn vehicle (fig. 10). Four new hydrogen engines, each developing 200,000 pounds of thrust, will be combined to give this stage a total of 800,000 pounds of thrust. This new engine will be a really big step in the development of hydrogen engines from 15,000 to 200,000 pounds of thrust. The big hydrogen engine is under development by Rocketdyne.

Here at a glance you can get a good look at the three Saturns (fig. 11). The first version, on the left, can put 10 tons of payload into low Earth orbit. It is also designed to put three men into orbit around the Earth. The first launching of the Saturn C–1, without a payload, is scheduled for later this year. With payload, it stands about 180 feet tall. It weighs about 500 tons at liftoff.

The second Saturn, in the middle, will be about 209 feet high. It will have three stages and will be capable of orbiting manned or unmanned payloads of more than 22 tons around the Earth, soft-landing a 1½-ton payload on the Moon and bringing it back to Earth, or putting instruments on Mars or Venus.

The third Saturn shown here is a rather radical departure over the other versions, in that the booster will be powered by two huge new kerosene engines, each of which develop 1.5 million pounds of thrust. This Saturn booster, then, will be twice as powerful, with 3 million pounds thrust, as the earlier version. The second stage will have the same four Rocketdyne 200,000-pound hydrogen engines, and the third will have the six Pratt & Whitney hydrogen engines with 15,000 pounds of thrust each. It can put almost 50 tons into Earth orbit, or fly a multiple crew around the Moon, or send 12 tons on a one-way trip to Mars.

Ten launchings of research and development vehicles are scheduled in the current Saturn program. The first three vehicles will be composed of a live booster and inert upper stages. On later launchings we will add live stages. Following the tenth launching in 1964, the Saturn C–1 rocket is expected to be operational.

We expect the Saturn deep-space rocket to be the major rocket for U.S. space exploration for a number of years. It is the first large rocket to be developed in the United States for scientific peaceful research.

Figure 12 shows where the Saturn will go when it takes leave from Cape Canaveral. You

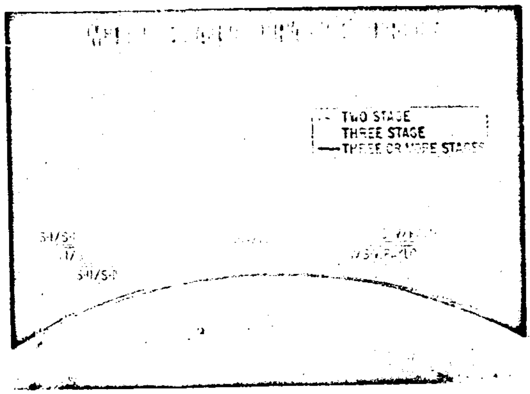

FIGURE 12

see the Earth and the various trajectories of Saturns going out on various peaceful space missions. Most people seem to think that orbital satellite operations take place at vast distances from the Earth. Actually, as you can see here in the scale drawing, these operations take place relatively close to Earth.

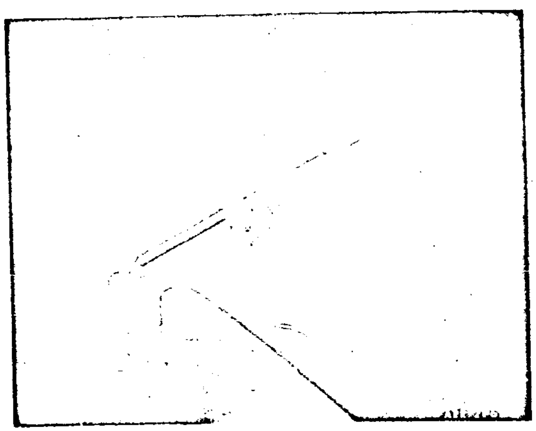

FIGURE 13

The first separation, as we see in figure 13, is when the booster separates from the remaining stage and Apollo capsule. The Apollo is not only an extension of the Mercury man-in-space program, it has other capabilities. For instance, men can use it to observe the surface and environment of the Moon before a manned landing takes place. The Apollo is also sufficiently flexible to serve as a manned orbiting laboratory—a laboratory where man can perform useful space research in a low Earth orbit.

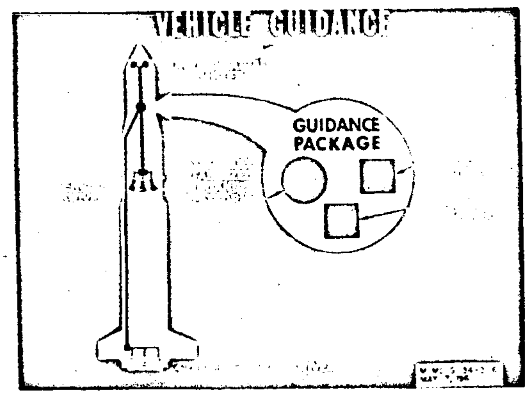

FIGURE 14

This orbiting laboratory is a necessary step leading toward a permanent manned space station. This will be the main application of the Saturn rocket, man into space.

In figure 14 we see in simplified form how the Saturn is guided. The basic components of the package are the guidance computer, the control computer, and the stabilized platform. On the eight-engine booster the four outer engines swivel as much as 10° to keep the rocket on course. All six engines in the second stage swivel, or gimbal as we call it.

Figure 15 shows a promising plan to recover Saturn boosters and thus save a lot of money. Rockets are usually considered expendable; but, by using this unique Rogallo kite, called a paraglider, we think we can return boosters and some upper stages to land and fly them again. Recovery would also let us make a close

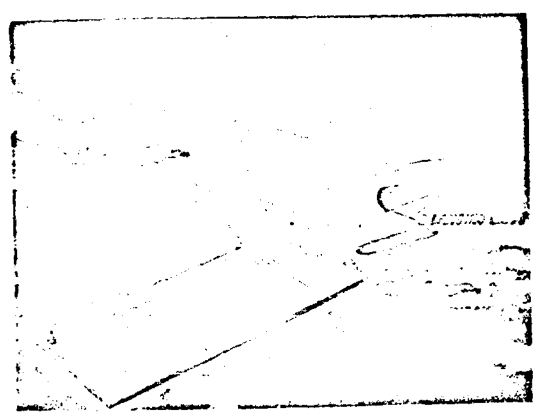

FIGURE 15.

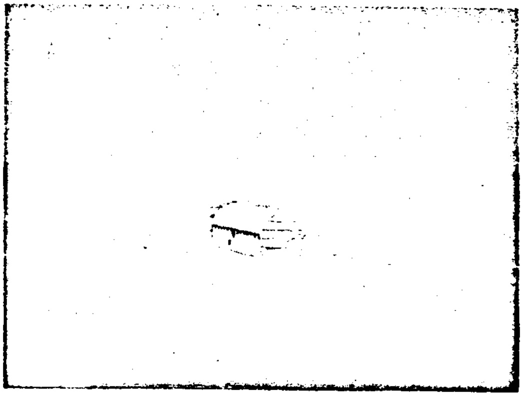

FIGURE 16

inspection of the intricate systems and see whether our 1000 channels of telemetry are telling us the truth about the information they send back from a flight.

After launching from the Cape, it could be landed either at the Grand Bahama Island or back at the Cape. The paraglider would actually be guided down from the ground, as you see here, through the Saturn's guidance system. Lines attaching the kite to the booster can be pulled in or let out to adjust the kite as it approaches the landing strip.

The special barge (fig. 16) was built because it's about the only way, at present, anyway, that we can get the Saturn booster from the Marshall Center to Cape Canaveral. It's a 2200-mile trip by river, the Gulf of Mexico, and the Atlantic Ocean. The skipper of this unusual craft describes the barge as a cross between a mine sweeper, a garbage scow, and a blimp hangar.

Moving the upper stages of Saturn by air is a possibility. A rather startling proposal by Douglas Aircraft has been made to carry the Saturn second stage on top of an aircraft in piggyback fashion, as shown in figure 17. We're looking into this scheme, as well as the possibility of transporting stages by dirigibles and gliders. The idea is to save time and thus speed up schedules.

Saturn is shown with a nuclear upper stage in figure 18. In this concept of a nuclear rocket, hydrogen is heated by passing it through a nuclear reactor and then exhausted

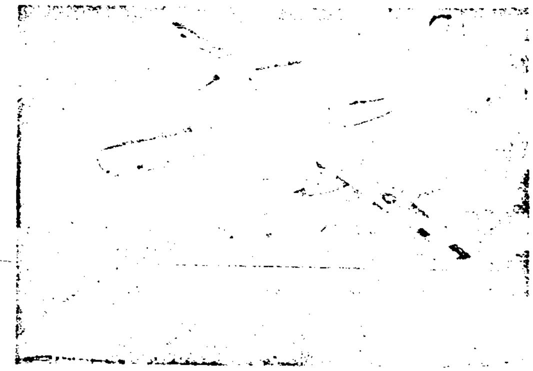

FIGURE 17

through a nozzle, yielding about twice the propellant economy you get with a hydrogen-oxygen engine. With this more efficient engine, smaller quantities of propellants will be needed, thus making our payloads a lot bigger. The NASA Centers are making a number of studies in this area. Also, NASA and the Atomic Energy Commission jointly are pushing forward the pace of the Rover development, as the

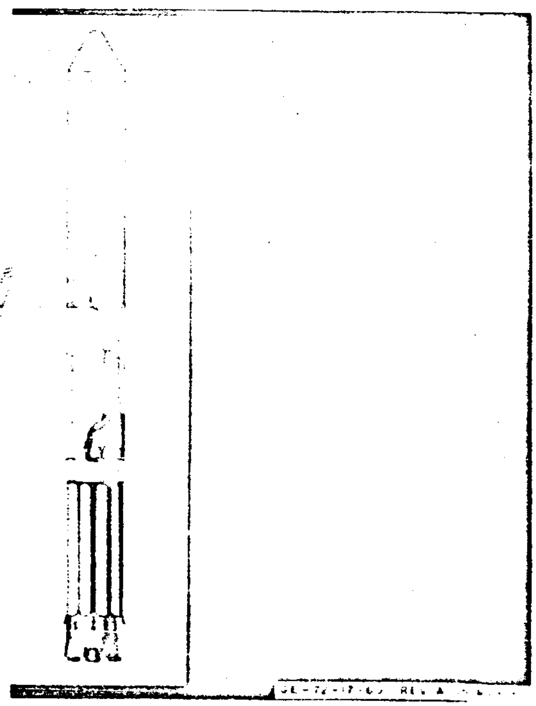

FIGURE 18

nuclear-rocket reactor program is called. We should fly our first prototype nuclear rocket by 1965.

As we approach manned space travel involving several men (and women, eventually, of course), we must put up much bigger payloads. To put these bigger payloads up takes thrust. Here is a dramatic example (fig. 19). The small liquid engine creates 188,000 pounds of thrust. Eight of these make up the Saturn first stage, which produces, as you now know, 1.5 million pounds. Then, at one stroke, comes a single engine that produces the same thrust, 1.5 million pounds, that the whole Saturn engine cluster produces. Both are kerosene engines. Two of these big engines also power the first stage of the Saturn C-3 mentioned earlier.

To express myself in more familiar terms, this big rocket engine produces 33,000,000 horsepower, compared with these two diesel locomotive units at the left, which together produce only about 4000 horsepower. Now, by clustering a batch of these big engines we can really achieve power.

And here is where we will need it. Figure 20 depicts the Nova space-vehicle concept. By clustering the Saturn C-3 boosters, those first stages with the two 1.5-million-pound single-chamber engines on the left, we come up with the clustered Nova vehicle in the center. For very high speed it would be advantageous to increase the propellant capacity of the top stage. Thus, Nova would offer us an escape payload of up to 70 tons.

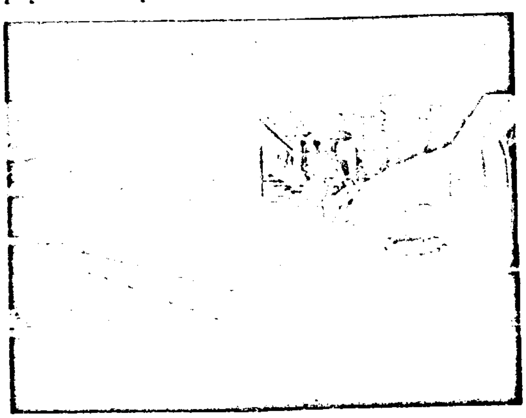

FIGURE 19

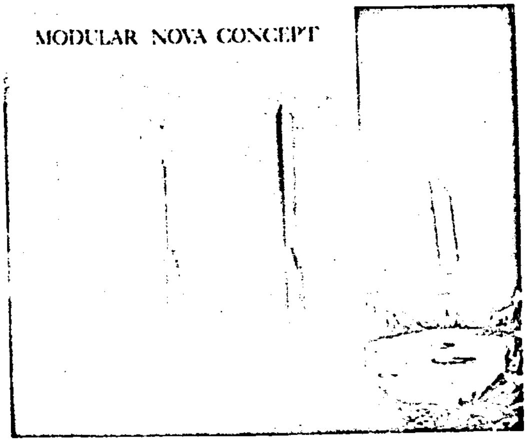

FIGURE 20

With Nova, we could land a locomotive on the Moon if any one wanted one there. What is more important, this Nova space rocket can put a spacecraft like the one on the right with three men on the Moon and return them to Earth, and at the same time leave 20 tons of supplies and equipment to support a manned lunar station. With a nuclear third stage, it could go into orbit around Mars and return to Earth later on. Nova vehicles of this class give us the most direct approach to manned planetary and lunar exploration. The booster will be a cluster of eight of the 1.5-million-pound single-chamber kerosene engines, developing 12 million pounds of thrust. For the second stage, we have two options. We can either use a modified C-3 booster, powered with two F-1 kerosene engines, or power this stage with eight 200,000-pound-thrust hydrogen engines developing a total thrust of 1.6 million pounds. In either case the third stage would have two of these same 200,000-pound-thrust engines.

Today, we know that the people, the President, and the Congress of the United States are behind our peaceful space-exploration programs. This support is most gratifying.

As you know, space exploration is not exactly inexpensive. But I assure you that all of us are very keenly aware of our responsibilities in this area, and we are using every penny as wisely and carefully as possible. There is no cheap shortcut available that will let us leapfrog ahead. It will take a lot of hard work and dedication.

But regardless of who pierces—first and best—the blanket of mystery that has veiled the secrets of outer space since the beginning of mankind, all will benefit. With the wise and steady effort now under way, man will soon be operating world-wide radio and television communications systems (thus relieving some of the present crowded channels). He will enjoy, through TIROS and NIMBUS satellites, world-wide weather-prediction services. This will be a particular boon to backward countries, farmers, shippers, and the aviation industry. Navigation will continue to improve greatly through the use of navigation satellites. Geodesy, the mapping of precise points and positions of the Earth, will be well served. And for the first time we will have a decent map of the whole world.

But the most important benefit we will derive from space exploration is, simply, knowledge—new knowledge, the satisfying of plain old curiosity—which is the most exciting thing in the world. Some say curiosity killed the cat, but it is today delivering mankind to a truer understanding of the universe.

Man hasn't yet reached the Moon, or Mars, or Venus. But each satellite and space probe and each manned flight is enhancing our knowledge of the environment awaiting us on forthcoming voyages. Some of this information is reassuring, some if it is disquieting. All of it increases our profound respect for that which prevails beyond the thin layer of our atmosphere.

I believe the challenge facing all of us is so immense that it will require the courage and confidence that can come only from knowledge and understanding. Challenges, however mighty, are not new to us. It is in the American tradition to accept challenges. The men who opened this continent and explored what is now the state of Oklahoma had the kind of spirit that transformed a virgin wilderness into the most complex social and economic structure that has ever existed on Earth. This was accomplished by the same kind of courageous and free men who will conquer outer space.

As the Roman philosopher Seneca said 2000 years ago, "There is no easy road to the stars."

If you figure it like the Soviets, we are now in the fourth year of the Space Age. Where will we be in the fifth year? Or the tenth?

With the continued support of the people and institutions of this country, I firmly believe that we of the Western World can and will get to precisely the place where we belong, and that place is squarely in the forefront of this, the greatest adventure in the history of mankind.

OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

ADDRESS BY SENATOR ROBERT S. KERR

PANEL DISCUSSION

Senator ROBERT S. KERR, Chairman
DONALD W. DOUGLAS, JR.
JAMES G. HARLOW
JOHN H. KOCH
SCOTT W. WALKER

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OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

ADDRESS

by SENATOR ROBERT S. KERR*

This is a historic meeting and a momentous occasion. It is a high honor to be called upon to lead a discussion of this kind. Candor compels that I confess that I am already as aware of my lack of scientific knowledge as you will be after I have spoken. And yet as new discoveries pass in review before our eyes in endless array, we realize that the least among us has learned but little, and the best informed has at least a lot to learn.

It is reassuring to me, and probably even more reassuring to you, that a panel of distinguished men of great knowledge has been assembled here to join in this discussion. Their presence spurred me to check my information very thoroughly. This checking was absolutely necessary in any event because many of the facts and figures dealing with space-age prospects are so fantastic that I would not otherwise feel justified in relaying them to you.

Tulsa was the natural choice for the site of the First National Conference on the Peaceful Uses of Space. Certainly it is an ideal place for us to speak of the nationwide opportunities for industry and education in the Space Age.

Oklahoma has a remarkable record in the development of her natural resources. Tulsa is the oil capital of the world, although just 50 years ago Tulsa was hardly more than a cow town on the prairie.

The countdown of favorable elements for industry here was made with accuracy and precision a few years ago by a great industrialist at the dedication of a new chemical plant at Muskogee. Muskogee, as most of you know, is one of many fine cities in the valley of the Arkansas River. A colossal transformation in the economy of this valley looms just ahead. Before 1970, according to a timetable that has our prayerful support as well as the full endorsement of the Government agencies involved, the Arkansas River and its tributary, the Verdigris, will be navigable to the surburbs of Tulsa. But even now, as it was stated at the Muskogee plant dedication, all the factors needed for vast industrial expansion are at hand. He said the factory had been located in Oklahoma because of the abundance of (1) fresh water, (2) low-cost electrical power, (3) unlimited energy fuel, (4) the high-quality labor force, (5) the finest climate, and (6) one of the best recreational areas in the nation.

That plant, designed to produce new fuel for use in aerospace projects, is typical of the decentralization and expansion of key industries we can expect in the coming years of space technology. This will not be an entirely new field for many Oklahomans, for in 1961, the expenditures of the Oklahoma aviation industry, including the outlays at several key military installations across the state, exceeded 336 million dollars.

It is the responsibility of the Senate and House Space Committees to review and help direct, through legislation, many of the civilian space activities of our Nation. Our studies in the past few months have given us great confidence that in its overall space program this nation leads the world. Certainly the recent flight from Cape Canaveral of Commander Alan Shepard brought home dramatically, not only to members of the Committee but to people throughout the world, the vitality of this effort. We must recognize, however, that a great deal

*Chairman, Committee on Aeronautical and Space Sciences, United States Senate.

of negative thinking still exists. There are those who judge our space effort in the light of their aversion to spending public and private funds to find and explore new frontiers because they cannot see an immediate profit. The forebearers of these negative thinkers probably were among the advisers to Queen Isabella and presented the same arguments against underwriting the equally unpredictable voyages of exploration and discovery by Christopher Columbus.

As was pointed out by Patrick Henry, there is no way of judging the future but by the past. The world changes and it changes at an ever more rapid rate. Discoveries made by the space researchers may have more significance to our future economy than any other single factor. When Michael Faraday showed Prime Minister Gladstone his new electrical generator, Gladstone asked, "Of what use is it?" Farraday replied, "Some day you may tax it."

Faraday had a sharp eye for the future, and there are many among us with equal vision. This country is not only indebted to Dr. Werhner von Braun and his group of German scientists for the decisive part they have played in developing our system of rocket weapons, it is also indebted to him and other men of great skill and imagination for their spirit and daring vision in assessing the space-exploration program's role in our total national effort. Dr. von Braun put it like this:

"Our entire civilization and particularly our economy depend vitally upon the continual discoveries we make. If we do not discover new things, then we cannot develop new markets and new needs, and our industry soon would be unable to employ all the many people it does. We have to keep stoking the machinery of our economy with new inventions if we do not want to run head on into a depression."

Economists tell us that the rate of growth of our economy depends to a large extent upon the investments made in new processes and in new product manufacture. The Department of Commerce reports that, although no exact statistics are available, the causes of the great complexity are our new-product practices. At least a tenth of the goods comprising our gross national product this year represents new designs, model changeovers, or recent evolutionary changes resulting from research and development. Research and development activities in the United States this year will exceed 13 billion dollars, of which approximately 8 billion will be financed by the people through our Federal Government. The remainder is being sponsored by private enterprise.

Twenty years ago the total outlay for research and development in this country was less than one billion dollars. Private concerns that have invested heavily in both basic research and the development of new products have shown the fastest growth in the past 20 years. Several surveys have shown that companies founded more than a generation ago have, to an overwhelming extent, made drastic changes in their production techniques and in their products. In fact, most of our largest companies that were in existence 50 years ago are now making money by selling services or goods then unknown. This Nation's economy was built on the philosophy of the better mousetrap, though gadgetry has given way to more sophisticated products and techniques achieved through science and technology.

This conference can be the launching pad for exploratory takeoffs into vast realms of new discovery. Frontiers heretofore undreamed of beckon us—frontiers of scientific exploration, medical research, industrial expansion, educational growth, and opportunities for world leadership. This meeting will help us reduce these challenges to immediate and local application, for in this audience today are many frontiersmen. Many of you have the opportunity to participate in a phenomenal era for our own educational institutions and industrial units now in existence and yet to be born—to participate in the expansion and development of these frontiers.

As a basis for discussion by our panelists, let me read quickly some of the signposts which are readily discernible, even though our roads may lead to yet unexplored areas.

Many companies saw these signposts years ago and have since traveled to the point that their entire effort is devoted to space or space-related products and services. Likewise, many of our educational institutions heard the knock of opportunity before it became the clarion it is today. These statements underline the importance of this meeting, which I consider of greatest importance in the era of discovery this nation has embarked upon. The United States and all other free nations of the world have grown and prospered as the result of imaginative thinking by citizens in all walks of life, citizens concerned with national defense and national prosperity and well-being; responsible, energetic, and open-minded, and beneficiaries of democratic institutions that encourage enterprise and effort in many diverse fields. It is in this spirit that this conference was called, for free exchange of ideas is a precious asset deserving fullest use.

We know that the development of space programs is vitally important for national defense. We must never be unmindful of the tremendous military implications. A few weeks ago the Secretary of the Air Force, Mr. Eugene M. Zuckert, warned, "Experience tells us we cannot count on Communist exploitation of space for peaceful purposes. America and her allies have no choice but to extend our influence into space to the end that no nation shall be disfranchised in space . . . the nation that dominates space can dominate the Earth."

But we see greater challenges to explore and utilize space for peaceful purposes. I am convinced that the nation that leads in exploring and using space for peaceful uses can best build, improve, and inherit the Earth; and, under God, dedicate it to man's highest purposes.

Although the most dramatic events associated with the peaceful uses of space technology may be occurring at Cape Canaveral or elsewhere, we do not need to look beyond the borders of Oklahoma to see clearly that this new age of discovery will soon bring significant changes in our lives and our ways of making a living. We already have heard here today the details of the weather-forecasting prospects. What a boon it will be when our forecasters can give Oklahoma farmers who produce wheat and cotton and peanuts and pasture more certain advice concerning the harvesting of their crops! What help it will be in planning for the most useful application of labor at planting time! And what a pleasure it will be to know accurately when good fishing, or golfing, or football weather is in the offing; to have an accurate weather forecast for the planning of recreation, for the designation of time for rest and relaxation, as well as for labor.

Another signpost held before us today can be labeled with one word: Communications. The revolution in communications that is inevitable as the result of our space sciences has come as a surprise to the vast majority of us. Few, if any of us, foresaw the practical use of weather-forecasting satellites. The development of reconnaissance satellites, which promise to become a shield against aggression, likewise have come along without advance notice. Better communications around the world resulting from the new satellite programs now under way will, in time, affect all of us. Who would have believed, 50 years ago, that the radio would become such a commonplace tool and convenience? Yet we now take it for granted that a taxi can be summoned, or a delivery truck dispatched, by shooting information via the ether from one set of vacuum tubes to another.

Population pressure alone will put great strain on our communication systems in coming years. In fact, all of the industrial aspects of space technology will be affected during the next decade by population growth. This country will be adding an average of 3½ million people annually and 1⅓ million people to its labor force each year during the 60's. Supporting the new commerce will require an average increase of nearly 2 percent in the gross national product annually, but if we are to improve our standard of living at the rate achieved in the past, the gross national product must be stepped up at least 3½ percent a year.

The use of electronics in our everyday lives is exemplified by the farm tractors that traverse the fields of Oklahoma equipped with a loudspeaker for the entertainment and information of the driver. This illustrates a vital new industry. Some of the fastest-growing companies in Oklahoma are those engaged in electronics. This type of manufacture tends to prosper where there are men of specialized knowledge. Oklahoma's aviation and oil industries have been closely associated with this technology. A recent survey by the Oklahoma Department of Commerce and Industry shows that this state has 29 plants manufacturing electronic equipment. The U.S. Department of Commerce has estimated that this industry will have five times this much output in Oklahoma by 1970. I wish I had the time to tell you, in detail, about some of the work being done by these plants. Right here in Tulsa are located the headquarters of several firms that have played vital roles in space research projects. They are engaged in building parts for computers, parts for test instruments, and complete training devices. Tulsa-made instruments helped send the Echo satellite on its way around the Earth. This big balloon is still seen as a pinpoint of light signaling the Space Age across our night skies.

Another Tulsa firm supplied radio positioning equipment for the Atlantic Missile Range, which assisted in the recovery of our first astronaut, safe and sound, and will be used in the tracking and recovery of future space capsules. The crosscurrents in today's industrial sciences defy simple description. At Cape Canaveral a few weeks ago we were shown skyscraper-like launching structures which, had we seen them in Oklahoma, we would have recognized as oil derricks. We were told, too, that oil itself plays an ever-increasing role in space programs. One interesting statistic in passing: It will take an average of 17,000 barrels of crude oil to produce the kerosene needed for the launching of the first stage of the Saturn rocket.

Instrument firms here and elsewhere throughout the Southwest have a huge stake in the computer industry, which is often described as the heart of space-age technology. One eminent scientist told me the other day that computers will become so important to our everyday life that we may give a new name to the Space Age in the not-too-distant future, calling it instead the Age of the Computer. This branch of science grows faster today than any other, for the computer today is the basic instrument in the acceleration of scientific knowledge.

Oklahoma can be extremely proud that the electrical engineers at the State University in Norman are now completing construction of a digital computer that will be one of the finest in the world for space-age calculations. This computer already has attracted a number of new research contracts to the University. Since most of these originated from outside the State, they will bring new income and new participation in space activities for Oklahomans.

One gets a grasp of the complexity of these giant thinking machines at Tinker Air Force Base near Oklahoma City, where a computer handles the inventory and shipping of parts for the entire B-52 weapons system of the United States Air Force.

Telephone company executives tell us they see an entire new area for major growth supplying data-transmission facilities. Machines are being developed that will transmit at speeds equivalent to 3000 words a minute, for the computer can gather and store information far faster than we ordinary mortals.

Time does not permit a review of the industrial potential of the Space Age. One can only cite a few isolated examples. One large aerospace company alone placed orders for half a million dollars worth of small parts in Oklahoma in 1960. Sixteen different Oklahoma concerns shared this business. This company tells me it placed subcontracts in 47 states last year with 12,126 suppliers, of which 73 percent had fewer than 500 employees.

Having mentioned the University of Oklahoma computer project, I would like to call your attention also to the outstanding Space Age activities at Oklahoma State University. The National Aeronautics and Space Administration has awarded a series of research contracts to the Research Foundation at Oklahoma State. In fourteen years of operation, the Laboratory at Stillwater has taken part in approximately 150 space probes and upper-air rocket firings. Contracts placed at this institution during this period have totaled over $1,500,000.

The projects at our two state universities are but a part of the intensive programs under way on those campuses, and on many other campuses over Oklahoma, to gear up for the Space Age. They do illustrate, however, that we need not go outside Oklahoma to find examples of what educators have done, are doing, and must do more of. My father used to say, "By knowledge, God created the heavens and the Earth." Francis Bacon's oftquoted adage, "Knowledge is power," was never truer than today, and, if there are degrees of truth, it will be even truer tomorrow.

Thus it is that we are deeply concerned with our learning processes, not only as they exist in our schools and colleges, but as they are made available to all citizens. This conference itself is a phase of space-age learning. I congratulate the Tulsans, the aerospace industries and trade associations, the Frontiers of Science Foundation, the National Aeronautics and Space Administration, and its other sponsors for making it possible.

The citizens of this country were rudely awakened to an educational crisis in 1957, when Soviet Russia launched Sputnik I. Many programs have been undertaken to meet the challenge thereby dramatized. Millions of people have gone to work on the problem.

To cite more examples near at hand will be a pleasure. Many Oklahomans had already seen the crisis coming and organized the much-heralded Frontiers of Science Foundation as a unique means of meeting it. This group with the help of educators and school patrons throughout Oklahoma conducted a survey of our state's educational system, with particular emphasis on science training. Officials of the National Science Foundation, a Federal agency, recently informed me that Oklahoma, as a result of this early start, has set an outstanding record. For instance, participation of Oklahoma teachers in National Science Foundation-sponsored institutes was 88 percent higher than the national average. Oklahoma's participation in the summer training program for high-ability secondary-school students also has been much better than the national average, the National Foundation tells me.

A few days from now, graduates will be streaming from the campuses of our high schools, colleges, and universities. Naturally, mathematics and engineering majors are the Oklahoma colleges graduates in greatest demand this year. A national survey last week showed that graduates with the engineering and accounting know-how to operate computers have the greenest field of all this year.

At the University of Oklahoma School of Aeronautical and Space Engineering, the faculty reports that 90 percent of the graduates had accepted jobs weeks before they began "cramming" for their final examinations. Most of those who hadn't accepted employment up to then were undecided whether to continue their studies at the graduate level or go into industry.

In the Space Age, education cannot and will not be reserved for our youth or for a relatively few adults in specialized pursuits. Adult education in many fields will be a prime need. Our technology already has outrun our educational resources in some areas. At the Oklahoma State technical school at Okmulgee, for instance, one-fourth of the 1300 students now enrolled are studying automobile mechanics. These enterprising young people are aware that the United States is short an estimated 250,000 automobile mechanics. Enrollment in electronics courses at this institution, which was created in 1946 when I was governor, has tripled in the past five years, they tell me.

Later this year a 4-million-dollar adult education center will be opened at the University of Oklahoma. This facility, financed 50-50 by the state and by the Kellogg Foundation, will enable thousands of our older citizens to develop new skills and new interests. Many of the short courses, clinics, and other sessions at this center will bear directly upon space-age activities. A recent congressional survey of the relationships of the various professions to this new field of endeavor underlines the importance of such centers. This study showed that space programs will have major significance for the professions—for doctors, lawyers, architects, construction people, transportation firms, and many other fields of endeavor.

Insofar as the development of research programs on our campuses is concerned, the emphasis is and will continue to be upon the individual faculty member who can fill the dual role of teacher and research leader. Currently, the National Aeronautics and Space Administration alone has in effect 175 active grants and contracts with 60 of the nation's colleges and universities. These contracts, totaling more than $17 million, are in addition to research grants from the armed services and from many privately endowed foundations and organizations.

The United States government today supports basic research in some 450 universities and research institutions in all 50 states and 12 foreign countries. I sincerely hope that such programs can be extended to more of our colleges, not only in Oklahoma but throughout the nation. College administrators take note: The people charged with dispensing these funds invariably give greatest consideration to proposals that come unsolicited from talented faculty groups with the ability to recruit strong graduate-student assistance.

One needs go no farther away than the University of Iowa to examine a truly outstanding story of university-sponsored research. Dr. James Van Allen, the director of the Physics Department there, pushed tirelessly for many years in the field of cosmic rays, and his efforts paid off with the discovery of the radiation belt that bears his name. Dr. Van Allen had conducted upper-atmosphere experiments at the White Sands Proving Ground in New Mexico for four years before returning to his native state in 1950 to head the college program. How this man scraped and saved to get the funds needed to finance his rockets and payloads for high-altitude research is a separate story in itself. Suffice to say that, after years of work, during which he carefully trained his graduate students and welded them into an unbeatable team, the discovery occurred. Perhaps the greatest stroke of genius was his forethought in designing a satellite instrument package that fitted both the Navy's Vanguard, which originally was to have launched this nation's first orbiting vehicle, and the Army's Explorer I design.

Dr. Van Allen's courageous curiosity keeps him going for higher and higher observations, first with balloons, then rockets, and now with satellites. All the while, he was and is training younger men to proceed with him into the unknown, to join in that noblest of callings, the search for knowledge. When Dr. Van Allen started his inquiries, the obstacles were great. Now, however, many paths have been laid open to the scientist, the engineer, or the businessman who desires a part in this adventure.

And adventure it will surely be. A few weeks ago all of us took part in an unforgettable episode of it when we shared Commander Alan B. Shepard's hair-raising ride in the Mercury-Redstone rocket capsule. We have tasted adventure, and we savor more.

A Washington columnist, given to clever though sometimes profane comments, summed up the common feeling the other day when he suggested that the motto on our coins be changed to read, "Toward God We Thrust." Though he probably intended to be facetious, so far as substituting mottoes is concerned, his remark rings true. For, while in God we trust, thrust we must.

The thrust is going to require a lot more than bigger and better rockets. More perilous and longer flights by our astronauts will inevitably follow. Virtually all the human race is involved in the race for space, or will be profoundly influenced by it. The Good Book says, "All things come alike to all: There is one event to the righteous, and to the wicked."

We can face this truth without a quiver, however, so long as we work to the best of our abilities with heart, mind, and muscle.

In its heart, our nation is pure and true. It stands for human dignity, for individual freedom, and for peace and goodwill.

In its mind, our nation is confident and clear. We have the brains and the know-how. We demonstrated this clearly when we chose to conduct our space-flight experiments without secrecy, that all might know and benefit from the knowledge gained by them.

We certainly have the muscle, the strength, and the will to win. Here in this audience there is evidenced the determination to succeed, to adjust our labors to fit the needs of the thing that has come alike to all mankind—the sudden dawn of the Age of Space.

Communities, cities, states, and nations; schools, colleges, and universities; business firms, factories, industries, and corporations that seek to go forward beyond what they have already done, without new ideas and new approaches and new dedication, are doomed to dismal disappointment.

The capsule that carried Commander Shepard to glory can never soar again unless it is powered by another rocket. The height and distance it achieved were in direct proportion to the power that propelled it, and it can rise again to greater heights and go greater distances if the power is provided.

So it is with all of us who scan the opportunities to participate in the Space Age. And so it is with our blessed country. We are now, as all before us have been, space travelers on our Earth. For our Earth circles the Sun as a mighty satellite hurled into everlasting orbit by the power of an eternal Creator.

We have the God-given talents—physical, mental, and spiritual—to power us into unlimited progress. Let us dare to do the best and the most which these talents will permit. Then we can truly say everything will be "A-Okay, all the way."

OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

1. PERSONNEL FOR THE SPACE AGE

by DONALD W. DOUGLAS, Jr.*

The Space Age is moving forward at a swift and ever-changing pace, and it is well that we have an occasion such as this to take a reading on the course we are following.

It occurs to me that there is an obvious and appropriate analogy to be drawn here. It would go something like this: We measure the speed of aircraft in hundreds of miles per hour, but we measure the speed of space vehicles in thousands of miles per hour. And I think it would not be incorrect to say that the speed of technological change has been stepped up at least as much.

We are fortunate, then, to have these few moments to contemplate this subject—if I may use such a leisurely word—and I am pleased to be able to participate in this session with you.

In talking of goals and directions, we might direct our attention to such matters as propulsion, guidance, structures, or any one of the many other elements that enter into our space activity. But the element I want to talk about is the human element—the men and women scientists, engineers, and technicians who are behind the hardware of the Space Age. These are the men and women who are providing the knowledge and the technical skills for our country to meet one of the most exciting challenges in its history; namely, the exploration of space.

The voyage of Columbus and the winning of the west were great historical events, but they did not involve the technical requirements, costs, hazards, and ultimate impact of the space-pioneering effort. If I may draw another historical comparison, I think the drastic technological changes we are now experiencing may cause this period to be known some day as that of the Second Industrial Revolution.

In the past few years we have begun working in technical areas never before invaded. To develop space systems requires new materials, new processes, new techniques, new machinery, and new facilities. To adjust to this technical revolution, industry—and this is also true of Government—is employing constantly increasing numbers of engineers, scientists, and technicians.

Let's take a look at this requirement.

What types of men and women are needed to send astronauts, and later commercial passengers, on journeys into space?

Perhaps the most dramatic way to illustrate the impact of the Space Age on our personnel requirements is to compare industry manpower needs today with those of a decade or so ago. At Douglas, for example, we employ more engineers and scientists than ever before in our 40-year history. The specialties of these men and women cover a much broader range of subjects than in the past. We have more personnel with doctoral or master's degrees than ever before. And the payroll for engineering is the largest in our company's history.

During World War II, engineering and scientific employees made up only 3 percent of our total employment. Five years later this force amounted to 10 percent of all employees. With the arrival of missiles, the number of engineers and scientists rose to 15 percent and, with the addition of space programs, now amounts to 20 percent of our total employment. In all likelihood this proportion will grow in the next 10 years to one technical employee to every two shop and clerical employees.

Let's turn to degrees. Twenty years ago

*President, Douglas Aircraft Company, Inc.

college students without formal degrees were often hired in engineering. Today, at least a bachelor's degree is required. However, with each passing day we are looking more and more for the engineer or scientist with the advanced degree. Tomorrow the minimum standard for the majority of engineering jobs may well become a master's degree.

Already it is becoming apparent that, as we hire more engineers with advanced degrees, it is becoming more difficult for the man with the bachelor's degree to compete for promotion. The Second Industrial Revolution has left us no alternative. We need men of knowledge, talent and creativity to spearhead our advance deeper into the Space Age.

Things just aren't as simple as before.

Almost as dramatic as the rise of the engineer and scientist has been the growing importance of the manufacturing technician at the expense of the assembly-line worker.

Today manufacturing is confronted with demands for new steels, plastics, and exotic metals; for new forming, casting, bending, welding, and bonding techniques; for printed circuits and for clean rooms, high-altitude chambers, and other environmental test facilities. The long production runs of ten years ago, with the need for thousands of assembly-line personnel, have almost vanished. Rather, the jobs are short-term and much more complex and sophisticated.

To meet these demands, management must constantly strive to upgrade its manufacturing personnel through training and hiring of more highly skilled technicians.

Throughout our company, and throughout our industry, the challenge of this transition is being met. Management is developing new organizational methods to meet it. New and vastly different facilities are being built to meet it. And people, engineers and factory workers alike, are meeting it with a combination of intelligence, hard work, and intensive retraining programs.

This happened right here in Tulsa, for example, where a Douglas division devoted principally to aircraft work has scored notable successes in producing second-stage vehicles for Thor-Able rockets fired over intercontinental distances to study reentry problems; and, later, upper stages for the Delta series of vehicles that Douglas builds for the NASA.

Thus far, we have talked about ways in which industry has been affected by this technical revolution. What about ways of softening that impact, of better adjusting to the demands of the Space Age? What are some of the mutual problems of Government, education, and industry, and how can they be reduced?

Let me emphasize that we feel the universities and colleges of the nation are doing an excellent job of strengthening their technical programs, of adapting their curricula to meet the needs of industry, Government, and business, and of encouraging a greater student interest in science, research, and engineering.

There are several areas in which education can help us. Some we have touched on, such as the need for more graduates with advanced degrees. Another is the shortage of trained personnel in such newly important fields as electronics, computing, solid-state physics, gas dynamics, and others.

Some areas perhaps aren't so obvious. One of our top engineers complained to me the other day that many young engineering graduates seem unwilling to take on drafting and design assignments. He pointed out that vehicle reliability stems in the main from the quality of the design of its small parts. "We need more men who are talented in mechanical design and have a pride of authorship," he concluded.

Then there is the problem resulting from the very swiftness of space progress. How are we to keep the engineers and scientists abreast of the state of the art after they leave the campus? There are programs that are proving helpful. These include in-house training classes, scholarships on a full- or part-time basis, expansion of company technical libraries, attendance at meetings of technical societies, and the encouragement of a desire for self-improvement.

This is a problem, not only of industry, but of education and Government, and it is being attacked by all three groups, separately and jointly. I am confident we shall find an answer to this problem, just as we shall to the many other problems that confront us in the Space Age.

OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

2. EDUCATIONAL OPPORTUNITIES

by JAMES G. HARLOW*

From the platform and in private conversation, it has frequently been observed here today that the United States has formally entered "The Space Age." This comment is not empty rhetoric: There is to be a "Space Age" and we certainly are in it, whatever that means, for the Congo is in it too; and I am by no means sure that it means the same thing for the Congo to be in the Space Age as it does for the United States to be in the Space Age. Despite some of the comments I encounter when I visit the Eastern Seaboard of our nation, it doesn't mean the same thing for Oklahoma to be in the Space Age as it does for the Congo, either.

There have been other "ages," some of them quite recent. The "atomic age" is hardly gone from the scene; the "electronic age" and the "air age" are visible among the various props of the public relations lads, and I certainly am not the only one in this audience who can readily conjure up images of the "automobile age." "Ages" come and "ages" go, but science and technology go on forever.

The flights of Shepard and Gagarin, dramatic though they are, are no more than giant exclamation points terminating that famous and prescient title of Vannevar Bush's OSRD report at the end of World War II: *Science: The Endless Frontier.* This is the basic fact to be kept clearly before us as we discuss industrial and educational change in Oklahoma.

Rocketry is an ancient technology. Three hundred years ago, Sir Isaac Newton told us how to launch a satellite. The Space Age isn't new in the minds of men, for it originated with Johannes Kepler and Sir Isaac Newton; since then, we have been working at the means of realizing it.

But perhaps even our time isn't as distinctive as we would like to think. The great European sea explorations of the fifteenth and sixteenth centuries, which included the discovery of America, were the result of technology, too. They were made possible by the improvement of an ancient gadget that is a commonplace today: the magnetic compass. As in our time, this period included much argument about who should receive the credit for the highly improved gadget; Marco Polo, a front runner for a time, was finally voted out, though he did run a fast race.

That our time is one of vastly increased rate of technological and scientific change, there can be no doubt; that our plight is enormously different from the plights of at least some generations that have preceded us there is considerable doubt. The Macedonian phalanx; Hannibal's war elephants; personal armor; the English longbow; the musket; the rifle; mass production of weapons through use of interchangeable parts—each of these was an invention that struck terror into the hearts of the bravest of men. Each in its turn was surmounted or counterbalanced; each in its turn was made the servant of peaceful purpose.

So it will be with the giant rockets; so it will be with the satellites. Today we fear hostile advantage; tomorrow with the same device we haul teak logs, make our law-enforcement officers safer, develop hobbies and lifesaving devices, and gain final supremacy over the wild beasts of the field and forest.

*Dean, College of Education, University of Oklahoma, and Executive Vice President, Frontiers of Science Foundation of Oklahoma, Inc.

The advantage of our time does not lie in escape from the impacts upon us of science and technology. Our advantage lies in the opportunity to turn war-inspired science and technology more rapidly to nonmilitary, nonaggressive purpose. This opportunity is to be found in the processes of research, development, and education—each of which is now at least partially understood, though not yet under rational control.

This conference is an admirable example of effort to put that understanding to work. Today and tomorrow, we are pondering the peaceful uses of space. For one thing, we hope that our competition with the Soviet Union will be gradually restricted to scientific, educational, and technological competition instead of threatening always to break into open warfare—something like the way in which the University of Oklahoma and Oklahoma State tend to restrict their overt feuding to the playing fields and the field houses, instead of attempting to do each other to the death in financial politicking. For another thing, we hope that we Oklahomans can relate ourselves constructively to this massive scientific-technological movement —and by constructively we mean relating ourselves emotionally, intellectually, and economically to this latest great breakthrough in human opportunity and insight.

Oklahoma's institutions of higher education have a tremendous opportunity before them in participation in the research effort of the National Aeronautics and Space Administration. NASA's basic directive in Public Law 85–568 emphasizes material contribution to the expansion of human knowledge of phenomena in the atmosphere and space, as well as contribution to the applied sciences side of space-vehicle development and space travel. Virtually all of the basic science departments of Oklahoma's universities can find research projects in this broad directive, if they but choose to do so. NASA's research grants in the newly established Life Sciences division, only through September 30, 1960, totalled more than one million dollars, distributed among sixteen universities and research organizations. NASA's engineering and physical science research is much larger in dollar volume and more widely distributed. With such enormous research support available, it would appear that all we have to avoid is avoidance itself.

At the moment, it is most difficult to see the directions in which graduate education should move in order to provide the intellectual resources with which to exploit the new breakthroughs. It has been known among philosophers that the so-called fields of knowledge are not the result of inherent features of knowledge, but rather the result of the questions we ask of our experience. To ask the question, for example, "How can man live in space?" is to ask a new question, one that requires combinations of today's fields of knowledge. Just as today's medical research frequently requires the cooperation of a radiation physicist and has thereby spawned a new breed of radiation-knowledgeable physicians and medical researchers, today's research questions related to space living are urging us in the direction of strong graduate specializations in biochemistry and biophysics, plus corollary specializations in engineering fields. However, only through active participation in the research effort itself can the faculties of Oklahoma higher institutions hope to move their graduate curricula in the directions that will bring us intellectually into the Space Age. Again, it must be noted that the fiscal resources for such research are available—through NASA.

Perhaps the stickiest, the most frustrating, and the most exciting of the problems of social adjustment to a rapidly changing technology are to be found in the educational arena. In Oklahoma specifically, how are 22,000 precollegiate educational staff people, not to mention their several thousand collegiate colleagues, to be moved into the new frontiers? Well-trained though they are by national standards, all these people received their basic training for teaching before Gagarin and Shepard. At least four out of five received their training before Sputnik I. Are teachers to continue in the current doctrine that post-certification training should be carried on at teacher expense, since it typically results in a minuscule increase in annual wage? Are school boards and school administrators to pick up the tab for modernization of teacher knowledge and teaching skills, following the practices of industry? Or, are we to place our reliance on extra-educational agencies, such as the National Science Foundation, and its various institutes, for the necessary modernization?

And what of the problem of locating and developing the brainpower necessary to cope with the new and expanding frontiers of science and technology, exemplified most brilliantly by the space effort and NASA? Apparently we are the first generation of humankind that genuinely needs the mass production of intellectuals. Our predecessors upon the human stage have found this category of human beings sometimes dull and sometimes provocative, mainly useful for starting and maintaining revolutions. However, we need intellectuals in wholesale lots. We need them to keep us on top of the changes in which we are immersed, to keep us up with our competitors for world attention, and to manage the cataclysmic social consequences of our enormous research and development expenditures. As Walter Lippmann once observed, the United States is a continuing revolution—a revolution in ideas, in economics, in politics, in the facts and in the artifacts of daily living. How are we to order our schools, our colleges, and our universities to maximize the development of the ablest of our youth, in order that the continuing revolution may be directed and controlled?

Oklahoma is making fine progress toward answers to these questions. Our in-service training programs for teachers are growing in number and in sophistication. Our development of programs and special opportunities for abler youth are moving along well. But much remains to be done, for we still have no general solution for the financing of faculty retraining at any educational level; as a consequence, curricular change is spotty and slower than we would like.

It has been a delight to me to observe the entrance of NASA into active educational effort. The Spacemobile on exhibit here in Tulsa is a fine current example of that effort. Oklahomans will be pleased to know that this vehicle will tour our State for two weeks following the close of the exhibit here; for this special opportunity we have again to thank Senator Kerr and Jim Webb. Through this tour, which will reach most Oklahoma colleges, at least a start can be made on sensitizing Oklahoma teachers to the fresh problems of our time.

In a very real sense, Oklahoma's opportunities and problems in the Space Age are those of the nation and of the world. The most primitive Congolese and the most aristocratic British lord may well expire together under the fallout of a single hydrogen bomb transported by a vehicle originally designed to place a man in orbit. But, in the world of the fifteenth century, who could foresee whether, after the establishment of contact, Europeans would go to the Orient, or whether the Orientals would move to Europe?

Our opportunity in Oklahoma is what we make it: We have and have had the same opportunity to gear our industry, our education, and our research to the Space Age as have other parts of the United States. Through this conference, our good senator, our good friend Jim Webb, and their colleagues are giving us new stimulation and new insights into the detail and the richness of the practical courses of action open to us. As we build and rebuild to seize the opportunities that are being pointed out, let us remember that the real problem for Oklahoma, the basic foundation on which we must build for the long run, is the development of our people—the development of a population for which innovation is a way of life and change is a synonym for opportunity. The development of such a population is the opportunity for education in Oklahoma.

OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

3. TECHNICAL TRAINING DEVICES FOR THE SPACE AGE

by John H. Koch*

When I was a youngster, the typical power washing machine was a broom handle attached to two gears going down to a spindle. And all day long, you pumped, and you washed your clothes through these two gears. Today, the average appliance that we have is almost computer-controlled. The modern washing machine has the circuitry in it that is program-controlled, and some of them are advertised as computer-controlled. It has a hydraulic system in it, a water hydraulic system that is very complex. It has a motor-driven system that is very complex, and the whole thing is controlled electronically from the little computer. The result is that the problem of technical maintenance or services for these appliances is very great. All of us have had experiences where it is almost impossible to get these appliances repaired. Now, the reason for this is that when you visit the appliance manufacturer, you will find they are training many of their technicians to assemble and disassemble the two-gear washing machine of 30 years ago.

To a certain extent, we have the same problem today in the Space Age. If we are going to accomplish the things that we set out to do in this country, then we must do something to accelerate the technical training problems that face us. As an illustration, it takes roughly 4 years of technical trade school and a 4-year apprenticeship to handle the technical complexities in one modern jet airliner. That's 8 years of technical training to totally understand the systems in one modern jet airliner.

I want to show in just a minute here, some very interesting technical training devices. These devices will shorten this learning process from one-fourth to one-third in length. Further, the retention of knowledge will be increased from 50 to 90 percent. Most everyone who hears me now will retain only 20 percent of what I say; and of what you see, you will only retain 30 percent, because you are passive. You are sitting still, you are relaxed, and so you will rapidly forget what you hear and see. On the other hand, if you say and do, you become active, and the training devices that I show you are the "saying and doing" types. The result is that you will retain 90 percent of what you say and do, as opposed to 50 percent of what you see and hear. These devices that you see now are the kind that require student participation in active circumstances.

Figure 1 is an Atlas missile training device. The propellant vessel, the sustainer engine, the boost engines, vernier engines, and so forth, are shown. All of the various flow lines on this device are operated from an instructor console. There are hundreds of malfunction insertion switches. The trainer clocks down in real time, advance time, or retarded time. All the vent windows are lighted and the device becomes a "doing" type machine, because as the operator goes through his countdown and launching, the instructor throws malfunction after malfunction at him, and he in turn has to attempt technical correction.

Figure 2 is one-hundredth of a solid-propellant missile. You can see the solid-propellant charge, just a portion of it, and our method of igniting the charge backed up with some electronic circuitry to take care of the charge. This trainer, when butted up to other training devices, would give you a complete missile. As we see it here, it is only intended

*Vice President, Burtek, Inc.

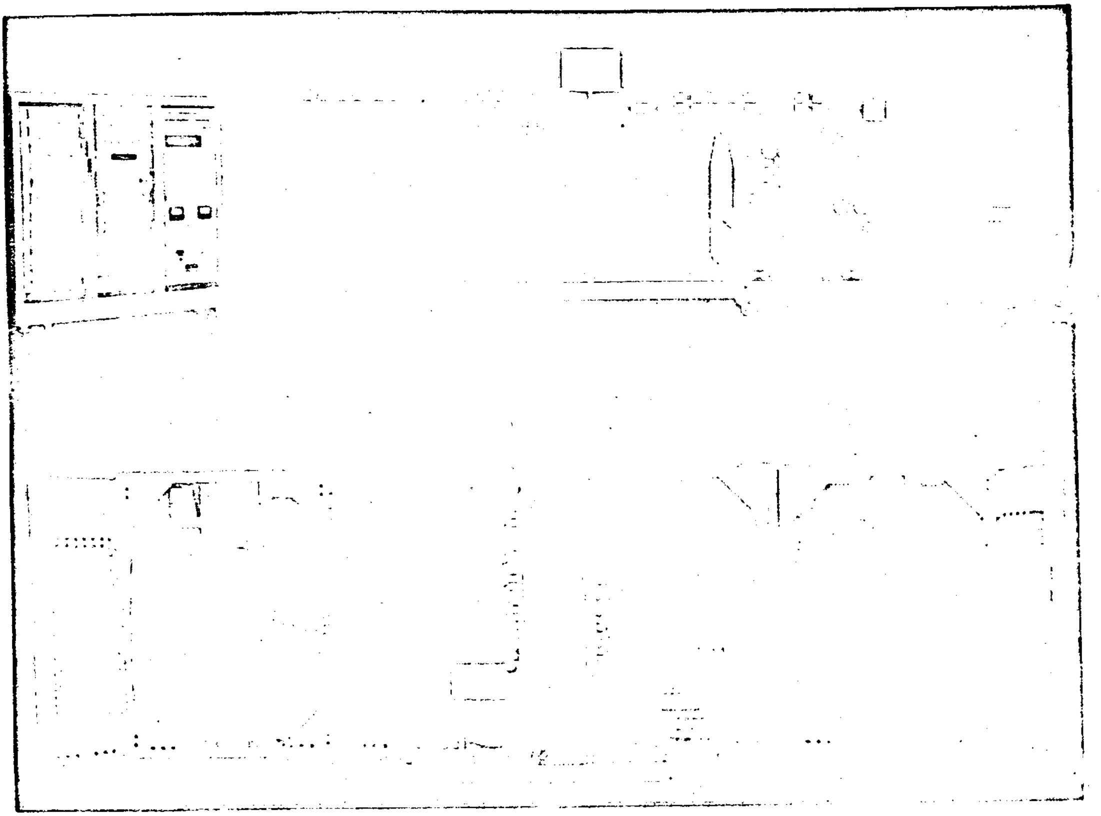

FIGURE 1

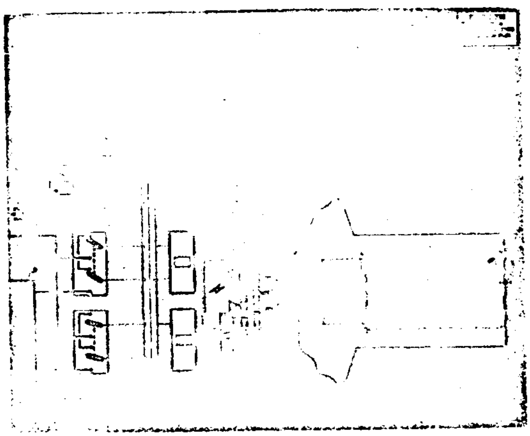

FIGURE 2

to teach the ignition portion of one solid-propellant missile system.

In figure 3 we see a portion of a guidance system where we have our individual thrust of fire, which we are going to control by means of swiveling or pivoting these points. We do it with inputs, electronic circuitry, and individual black boxes, so to speak, which will do the input

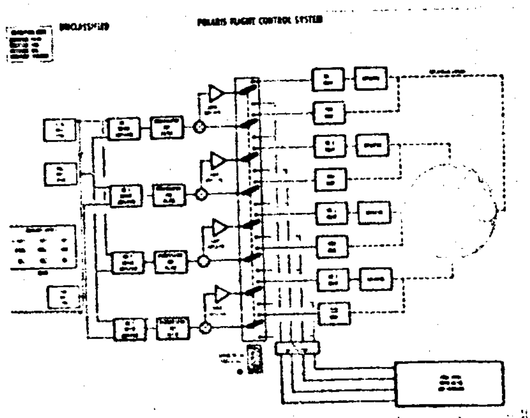

FIGURE 3

functions. The instructor and students come up and operate this unit: on the side of the trainer we have malfunction insertion switches that we can insert to make different malfunctions occur. On the back of the trainer, this unit is completely gimbaled and swiveled. All these lines light with back lighting to show what current flows you are getting and what action you are getting.

Figure 4 is a small launch console, where we have individual indicator lights all back-lighted. The instructor can throw these problems at the student as he attempts his launch. This is only one part of a large launch system.

In figure 5 we see a digital computer teaching machine. With this device, we can patch cord from each of these different coated electronic computer symbols. As we place our patch cords between the symbols, we can build a computer right in front of the students' eyes and then ask a student to come up in front of the class and build a computer himself.

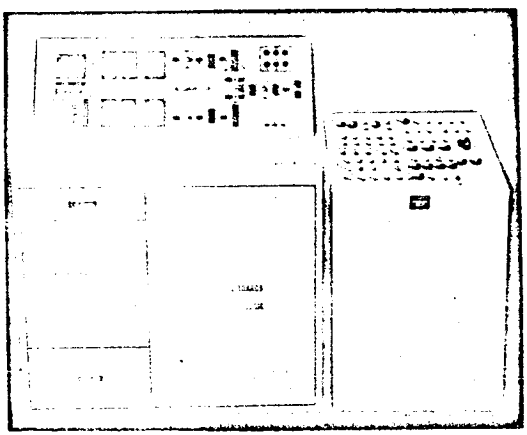

FIGURE 4

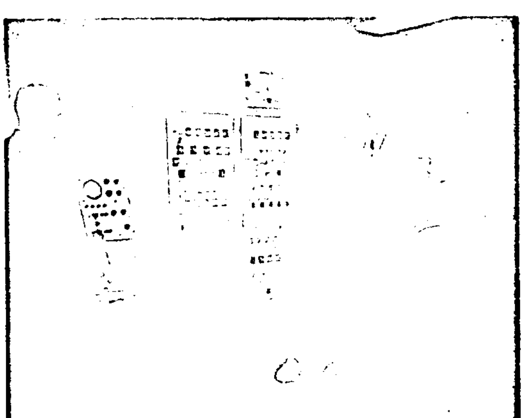

FIGURE 5

A small printed-circuit training device where the student makes up his own little flip-flop or his own little adder circuit and so on is shown in figure 6. So we have miniaturized computer

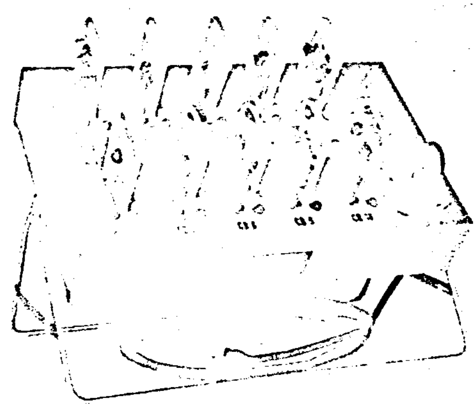

FIGURE 6

printed-circuit training devices that are used to train Navy missile technicians in this case, how to maintain the delicate mechanisms that go into the makeup of the typical computer circuitry.

A jet-engine demonstrator device is shown in figure 7. Technical instrument outputs are being recorded, and flight instrument readings taken. The operator inserts his normal opera-

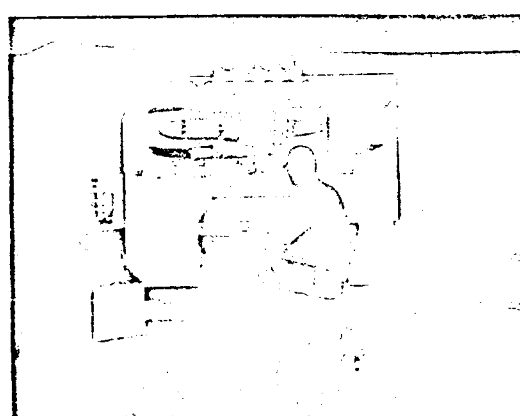

FIGURE 7

tion. The engineer manages the systems. The instructor throws problem after problem at them to see how they solve these technical problems as they occur. So this is an operator training device.

In figure 8 we see a typical flight director that you would have in any modern jet and in

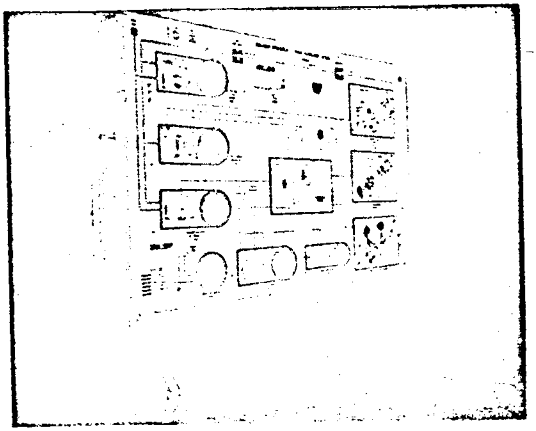

FIGURE 8

almost any spaceship that will have to come back into the Earth's atmosphere. We shall need instruments to tell us our speeds, altitudes, air densities, temperatures, and conditions. We do this by a computer mechanism that then feeds the inputs into each of the instruments. The instructor throws malfunctions at the students through these switch controls and expects the students to solve the problems on the front. Again, a "learn by doing" device, which causes the student to retain 90 percent of what he learns instead of only 50 percent.

A modern pneumatic system that was not in existence before the jet age is shown in figure 9. We have all these different things controlled through air under pressure and under temperature. Again, on the side of the trainer we have insertion malfunction switches. We have

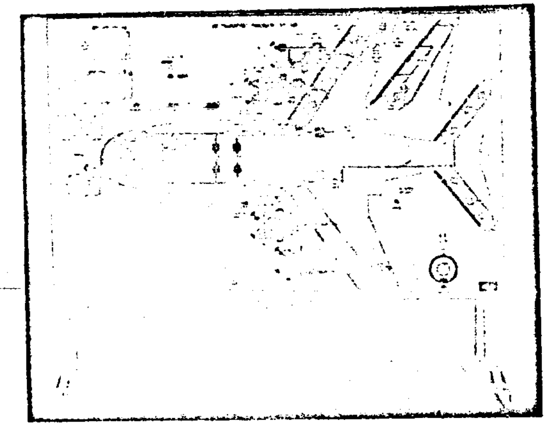

FIGURE 9

instrumentation that would be required in this kind of ship; in this case, it's a DC-8 airplane. The same requirements would exist in a spaceship coming back into the Earth's atmosphere. Shepard's small space capsule had a system, believe it or not, miniature, almost as complex as this.

I have one other item I would like to mention to you, and that is that the biggest problem I think we have today in the Space Age is the problem of transfer of knowledge from highly skilled engineers to the average man who does not think in terms of symbolism, but thinks in terms of actual hardware. The transition from the engineer's mind to a practical machine that will accomplish what we want it to do is very difficult. It's the understanding between two people: its communication, that is always difficult. Now, many firms—I should say several firms, not many—manufacture this kind of training devices. The ones that you have seen here were all made in Oklahoma. If anyone desires further literature, there is a great deal of literature on this subject available to those of you who have technical problems in this transfer of knowledge.

OPPORTUNITIES FOR INDUSTRY AND EDUCATION IN THE SPACE AGE

4. THE CHALLENGE OF THE SPACE AGE TO EDUCATION

by SCOTT W. WALKER*

The conquest of space has dramatically caught the eye and the mind of all of us. The public realizes the urgency and the broad importance of this exploration of the new frontier. They recognize that its success is based on science and technology. As never before, the world sees science in a new role and as a major force in determining mankind's future.

This awareness presents a challenge but yet an opportunity to education in the United States. The opportunity is here for us to improve, strengthen, and emphasize the importance of our educational process. These must start in our elementary schools and be carried out through high school and college.

Specifically, our curricula, the course offerings and their content, must be improved. To make science understandable to all, we must increase and strengthen our science courses. We must strive for more mathematics in secondary schools and raise the level of required mathematics in college, not only for science and engineering but for liberal arts and business. A country where computers are becoming a vital part of much of every day business and endeavor must have a mass who understand their concept and many who can operate them.

The space program and the many civilian benefits that will flow from it will demand more and more scientists and engineers. We must, therefore, attract more bright students into these professions. We must have them to succeed.

The need is probably greatest for engineers. The glamour of the Space Age seems to imply science to many, and the science enrollments have thus benefited. But the vast majority of the required skills—the manufacture of equipment, the instrumentation, the communication problems, the propellant systems, the so-called "hardware"—are for the appliers of science, the engineers. Not that we do not need more scientists and scientific discovery, but the space program is largely technological and requires a new emphasis on the importance of engineering.

Most of the space-age scientists and engineers cannot do with just four years of college. Many more should continue into graduate work. This then means greater opportunities must be provided for graduate study, with a corresponding increase in graduate programs and the establishment of more graduate schools.

The educational system, particularly our universities and colleges, have an opportunity to set up refresher courses for retraining those who have been out of school for a time. We should, also, offer special courses to train for specific needs.

Probably the most striking aspect of the educational opportunities lies in the realization that the entire work force must become more technically skilled. No longer does this country's economy rest on a broad base of unskilled labor. We do not need brute manpower, for now our needs are for highly trained skilled technicians throughout the labor spectrum. Therefore, our school systems must provide background education and training to ensure this kind of work force. This strongly suggests new schools to train technicians, not just trade schools or

*Dean, College of Petroleum Sciences and Engineering, University of Tulsa.

manual training, but modern-minded institutions dedicated to filling the needs of the employers and the workmen.

We believe that all curricula should be properly composed of studies in the skills of communications; the sciences, both physical and social; and that which is refreshing, creative and pleasurable—the arts. We are all doing much today to reach the right balance among these and the best paths to these goals. Perhaps the greatest benefit that can come from the conquest of space then is the awareness of science and from that the realization that the unifying discipline of modern education lies in modern science. When we recognize the power of the scientific method, which is simply the calm, orderly development of human thought, perhaps we can begin to apply it to all our problems. Perhaps the scientific method applied without prejudice to social science can lead us closer to our continued striving for peace and orderliness in human relations.

ADDRESS BY JAMES E. WEBB

ADDRESS

by JAMES E. WEBB*

No one could live in or be associated with Oklahoma for almost ten years, as have my wife and I and our two children, without realizing that this is a land of tremendous space and boundless horizons; with the outlook of the pioneer; capable of projecting into the challenging new frontier of space the competence, the willingness to experiment, the restlessness, and the personal courage and drive of the great Southwest. I know that through your great universities and colleges, through the efforts of your leaders in every field, and through such activities as the Frontiers of Science Foundation of Oklahoma and this First National Conference on the Peaceful Uses of Space, you are determined to build here a modern scientific innovative culture that will furnish leaders for the Space Age in the vigorous tradition you have always maintained. Our national space effort needs these qualities, and it needs Oklahoma and the Southwest.

Fresh from my intimate experience with the ferment of the modern Oklahoma frontier, I have had no difficulty in feeling at home on the space frontier—or indeed in President Kennedy's New Frontier. It was only necessary to change the habit of looking forward to the habit of looking outward.

Three and a half years ago, a short time even in the history of a new state like Oklahoma, the Russians were clearly ahead of us in space. They had launched the first manmade Earth satellite—Sputnik I. Since then they have sent 12 vehicles into Earth orbits, including the spaceship that carried Cosmonaut Gagarin around the globe. Although only one Soviet satellite is still in orbit, it is important to keep in mind that five of them weighed in the neighborhood of 10,000 pounds, and that three of these large vehicles have been recovered from Earth orbits.

In this same period, the United States has mounted a determined, major effort in the field of space exploration. We have drawn together in the National Aeronautics and Space Administration more than seven laboratories and space-flight research centers. The United States has placed in orbit 39 satellites, of which 22 are still circling the world, with nine still transmitting signals and valuable scientific information about our space environment. And just two weeks ago, openly, before the eyes of the world, we conducted the first Project Mercury man-carrying suborbital flight. You all know that Alan Shepard was the Astronaut.

During the period since Sputnik I, we have evolved the technology that made this giant stride possible. We have also drawn heavily on the bank of scientific knowledge accumulated over many years by means of telescopic observation of the phenomena of the universe, filtered through the veil of the Earth's atmosphere. On this scientific and technological foundation, we have developed means of designing spacecraft and of rocketing them into space packed with electronic equipment to isolate, measure, and observe specific phenomena. Data gathered by our satellites and probes have been radioed to Earth. This enormous flow of information is being analyzed continuously by the most modern computer systems, and we are distributing the results to scientists in every nation. Thus we have achieved a position of open science, openly arrived at, by spreading these new examples of the puzzles and problems that every great scientific advance generates, to the largest possible number of able minds for interpretation and solution.

As an example of how this system works, on March 11, 1960, Pioneer V was launched by a

*Administrator, National Aeronautics and Space Administration.

Thor-Able rocket to gather scientific data from deep space and to test communications over interplanetary distances. This deep-space probe weighed 94 pounds and contained two radio transmitters and receivers. In it were instruments to measure radiation streaming from the Sun, the spatial distribution of energetic particles and medium-energy electrons and protons, the number and density of meteoric dust particles striking the probe, and the strength of magnetic fields.

We were able to communicate with Pioneer V for a distance of 22 million miles and through it confirmed the existence of an electrical ring current circling the Earth at an altitude of 40,000 miles, the existence of which had been speculated on by geophysicists for more than 50 years. Pioneer V also measured an intense zone of disturbed magnetic fields at distances of 40,000 to 60,000 miles from the Earth, revealed that the boundary of the Earth's magnetic field is twice as far from Earth as had been previously supposed, and reported the first direct observation of pure cosmic rays at altitudes completely free of the Earth's atmosphere. This observation was made three million miles in space.

I could list many other achievements in this 3½-year period, such as the discovery of the Great Radiation Belts, now named the Van Allen Belts for Dr. James Van Allen of the State University of Iowa, one of the eminent scientists working with the Space Administration. I could mention that our first weather satellite, TIROS I, completed more than 1300 orbits of the Earth and transmitted more than 22,000 pictures before we lost communication with it. I could go on to mention Echo I, NASA's brightly twinkling, Earth-orbiting balloon which has been seen by millions and which has proved the feasibility of using satellites to reflect radio and other electronic signals. But I think I have made the point that the U.S. space effort has progressed in the 3½ years since man fired into orbit the first artificial Earth satellite.

In so short a time, while carrying out much of the activity I have outlined, the work force of the National Aeronautics and Space Administration grew from 7966 at the outset to 18,000 now. Our annual expenditure of funds rose from $145,490,000, during fiscal year 1959, our first year of operation, to what we estimate will be about $760,000,000 when fiscal year 1961 ends this June 30.

I believe it is fair to say that during this period the United States achieved first position in space, science, and technology and merited the confidence of the world scientific community. But there was one major field in which we did not make the necessary effort to achieve first position. This, unfortunately, was the area of building the large, high-thrust rocket boosters required to lift heavy payloads into space and to achieve sustained manned space flight. The U.S.S.R. did make the necessary effort and has reaped the benefit in world-wide acclaim.

So much for the past 3½ years. My own entry into this highly complex new dimension came 3½ months ago, when President Kennedy sent a message that I received while attending an Oklahoma City luncheon in honor of Senator Kerr. I can only surmise what went on in past years, but I know personally the intensity of work over the past 14 weeks.

There was the driving demand by the President and the Vice President that every facet of the requirements to recover our lost position be examined and evaluated.

There was the penetrating analysis of our past weaknesses by the Vice President, based on his experience during his 2 years' service as Chairman of the Senate Committee on Aeronautical and Space Sciences, with the follow-up of Senator Kerr, who succeeded him as chairman of that committee.

There were the incisive and meaningful sessions with the Secretary of Defense and the Chairman of the Atomic Energy Commission to bring the diverse elements into harmony in the form of a national space program.

There were the long and detailed presentations to the Director of the Budget so that he might test the validity of our conclusions and assimilate the facts that would permit the President to weigh the requirements for the space program against the other urgent requirements of defense and national interest.

There was the decision of the President that the key to retrieving our position lay in determining that we could no longer proceed with the Mercury one-man spaceship as if it were to be the end of our program, but that we must—even in a tight budget situation—present to Congress the urgent necessity for committing ourselves to the giant boosters required to power the larger craft needed to accommodate crews of several men on long voyages of deep-space, lunar, and planetary exploration.

Funds were increased to speed up the Saturn C–2 booster and the large single-chamber 1.5-million-pound-thrust F–1 engine, which will be one of the basic building blocks for Nova, the biggest rocket we have yet programmed. That is to say, we shall use the F–1 rocket as our basic building block unless the new decision of the President, announced yesterday—that we will parallel development of this liquid-fuel rocket with a solid-fueled rocket—produces a better and more powerful engine using some type of solid propellant.

Thus, the first major decision of the new Administration in the field of space was to step up the big-booster program to provide lift for larger and more advanced spacecraft.

The intensity of the effort pervading the past 3½ months did not end for me with President Kennedy's decision. At the same time that we were presenting the new program to the Senate and the House committees, the National Aeronautics and Space Council was being reorganized and the leadership of its Chairman, Vice President Johnson, was coming increasingly into play. The President asked the hard questions. The Vice President demanded the work to provide the answers. Those of us charged with getting the facts could see little difference between night and day, day in and day out, weekends and holidays.

We did manage to do the work. Based upon it, the President made his decision, and yesterday he announced major new goals for the nation and new programs to achieve them.

The fiscal year 1962 authorization request for the National Aeronautics and Space Administration is now increased to $1,784,300,000 or by 61 percent. The Space Agency expenditures for 1962 are now estimated at $1,380,000,000, or an increase of 43 percent.

The first augmentation of the space program by President Kennedy in March was primarily for the purpose of speeding up the booster and propulsion components whose development must precede an expanded program of manned and unmanned exploration of space. Further increases in this area, aggregating some $144.5 million, are included in the requests made by the President yesterday. Included is the initiation of a Nova vehicle of very large thrust, with sufficient power to land men on the Moon and return them to Earth. The increased request also provides an additional $130.5 million for Apollo, which will lead both to a three-manned Earth orbiting laboratory and a manned lunar-landing spacecraft. $66 million is requested for an accelerated effort in research and exploration of the environment around the Earth, around the Moon, and in the space between. Funds are provided for a study of the problems of return to Earth from flights around the Moon at re-entry speeds up to 25,000 miles per hour, which will generate extreme heat.

Thorough studies of radiation problems will be conducted, including an analysis of solar activity over the past 50 years in order to predict, if possible, the periods of extreme radiation that man must avoid.

In President Kennedy's new request, there is an item of $50 million to expedite the development of solar cells, transistors, and other components and to demonstrate transatlantic television, as well as to bring into being the kind of satellite communications system needed to meet governmental as well as commercial requirements.

In the area of meteorological satellites, there is an increase of $22 million to expand the TIROS flight program, and, in addition, the President has requested $53 million for the Department of Commerce to enable the Weather Bureau to proceed without delay toward the development of a world-wide meteorological satellite system based on the NIMBUS satellite now under development by NASA as a follow-on to the TIROS series.

In connection with NASA's program of speeded-up research and development of liquid-propellant engines, an additional $15 million is provided to accelerate the 1.5-million-pound-thrust F–1 engine program, and $58 million is provided for long lead-time propulsion-development facilities such as static test stands for single and clustered engines, facilities for testing booster stages powered with clustered engines, and design of new launch facilities for the much larger flight vehicles to come in support of the manned lunar effort. The largest booster vehicle funded in this program is the Nova. $48.5 million is provided to start work on a liquid-fueled Nova flight vehicle.

The Department of Defense through its Minuteman and Polaris developments has great capability in the field of large solid-propellant rockets. Therefore, solid-propellant booster stages for the Nova vehicle will be developed by the Department of Defense in parallel with NASA's liquid-fueled stages. The Department of Defense budget will include $62 million to begin work in fiscal year 1962. This means that both the liquid- and solid-propellant technologies will be driven forward at the rapid rate needed to assure the earliest availability of a Nova vehicle. As soon as the technical promise of each approach can be adequately assessed, one will be selected for final development and utilization in the manned space program.

Included in the requests is $23 million additional for the Rover program for NASA's share in the cooperative NASA-AEC project looking toward a nuclear-rocket engine. This includes $15 million for engine test facilities, which should be started now in order to achieve the earliest feasible flight date.

From the preceding it is clear that the President's requests, taken as a whole, establish a pattern of effort that adds up to a vigorous, well-rounded national space program. There is wide participation by many departments and agencies.

This program, in order to be successful, will require a sustained and highly paced national effort over a number of years. The President's action today not only steps up the program for the first year but also contemplates an increased tempo for future years.

To provide you with perspective on the dimensions and stage ratings of the Nova vehicle that will be used to land the Apollo spacecraft on the Moon and return it to Earth, listen to these figures:

The overall height of Nova will be some 360 feet—60 feet taller than a football field is long.

The diameter of the first stage will be some 50 feet, and of the upper stages some 25 feet.

In one version, the first stage will consist of eight clustered F-1 engines, each developing a thrust of 1.5 million pounds, using conventional rocket fuel. In cluster, the engines will produce a total thrust of about 12 million pounds.

This version also calls for second and third stages fueled with liquid hydrogen and liquid oxygen.

The Apollo spacecraft will carry its own propulsion system, retrorockets for soft lunar landing, and other rockets for takeoff from the surface of the Moon and return to the Earth. Apollo will weigh about 150,000 pounds.

Since the early days of World War II, the American people have faced many crises and have had the courage to make the hard decisions. The war effort was mounted and our arms were victorious. In the postwar world our deepest hope and desire was that the people of all lands would share basic individual fulfillment in peace, freedom, justice, and continuing progress. We were confronted instead with the cruel reality of a powerful despotism, bent on burying us along with the basic tenets upon which our society rests and from which it draws its strength.

We Americans are a pragmatic people, and we have always adopted new measures to meet new conditions. In the postwar period major milestones were passed with the adoption of the Marshall Plan, of the North Atlantic Treaty Organization with its military assistance program, support of the United Nations' action in Korea, the landing of troops in Lebanon, the Berlin airlift, and others that you can recall.

Now we are faced with another national requirement that will commit us for many years to a major undertaking in which second best has proved not good enough. All Oklahomans can be proud that at this First National Conference on the Peaceful Uses of Space the position of the United States in the competition for scientific and technological supremacy is presented clearly at a time when the President is calling for the support of the nation.

In conclusion, let me make it clear that all of the effects of the national space program will not be confined to outer space itself. These effects will go beyond the impression they make in the minds of men around the world. You as a citizen, as a worker, as a parent, as a patient in a hospital, will feel them in your daily life. Already our push into space has produced a ceramic that is made into pots and pans that can be moved from the coldest freezer into the hottest flame without damage. Our study of foods best suited for space flight will lead to improved nutrition for the earthbound. Space research has created new materials, metals, alloys, fabrics, compounds, which already have gone into commercial production. From our work in space vacuum and extreme temperatures have come new durable, unbreakable plastics that will have a wide variety of uses, such as superior plumbing and new types of glass adapted for windows that will filter intense light. Our scientists have devised minute instruments called sensors to gauge an astronaut's physical responses in space, to measure his heartbeat, brain waves, blood pressure, and breathing rate. These same devices could be attached to a hospital patient so that he could be watched by remote control. In the future every patient's condition could be recorded continuously and automatically at the desk of a head nurse.

More than 3200 space-related products have already been developed. These come from the 5000 companies and research outfits now engaged in missile and space work. From this new industry will emerge new jobs that will help take up the slack of unemployment.

Those of us who are working in the national space program are convinced that a large part of our future as a nation is at stake. We appreciate the support of those of you who have come to this conference to apply your minds to the space problem, to understand its implications, and to make your own contributions to it.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

PANEL DISCUSSION

L. A. Hyland, Chairman
Paul F. Bikle
James R. Dempsey
Robert Gilruth
W. Randolph Lovelace, II
J. S. McDonnell
O. J. Ritland

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

1. X-15 AND DYNA SOAR MANEUVERABLE WINGED RESEARCH VEHICLES

by PAUL F. BIKLE*

This country has had a continuing effort in manned rocket research aircraft since the first penetration of the "sound barrier" by the X-1 in 1947. The latest of these aircraft are the X-15 and the Dyna Soar. Both are maneuverable, piloted aircraft designed to investigate the problems associated with supersonic and hypersonic flight: and both are of great interest in devising techniques to give the astronaut as much freedom as possible in the control of his reentry and return to the Earth in a safe and practical manner. Time available will permit only a brief description of each project.

The X-15 structure is of Inconel X to withstand aerodynamic heating that will raise the skin temperature to 1200° F. In figure 1, a cutaway view of the X-15 shows the pilot's cockpit

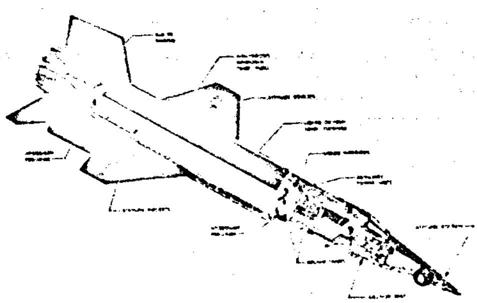

FIGURE 1

in the nose; behind this is space for 1300 pounds of research instruments, which are the payload. Behind this are the propellant tanks for the liquid oxygen and ammonia that are fed to the 57,000-pound-thrust engine in the tail. The short wings are much like those of a conventional F-104. A large, wedge-shaped vertical tail provides directional stability and control. Large horizontal surfaces are moved together for pitch control, and differentially to provide roll control. There are small rocket-type reaction controls on the wings and in the nose for control at altitudes where the aerodynamic surfaces are no longer effective.

Figure 2 shows the performance envelope in which the X-15 was designed to operate: speeds to 4000 mph (Mach 6) and altitudes of 250,000 feet with an additional capability to achieve higher altitudes, depending on the results obtained from tests within the design flight envelope. The research program is progressing at a steady rate in a step-by-step buildup to the maximum performance. The shaded area is the portion of the envelope that has already been explored. Best speed has been about 3100 mph (4.6 Mach number); maximum altitude,

X-15 PERFORMANCE

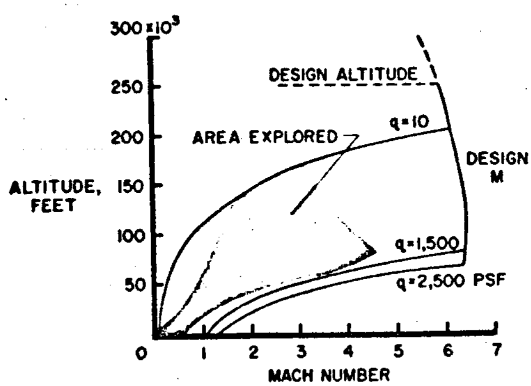

FIGURE 2

*Director, Flight Research Center, National Aeronautics and Space Administration.

169,600 feet. Problem areas have been relatively minor in nature, and there is no reason to believe that the primary goals will not be achieved before the end of this year.

Figure 3 shows a typical research flight. The X–15 is carried aloft and launched from under the wing of a P–52, as shown in the upper

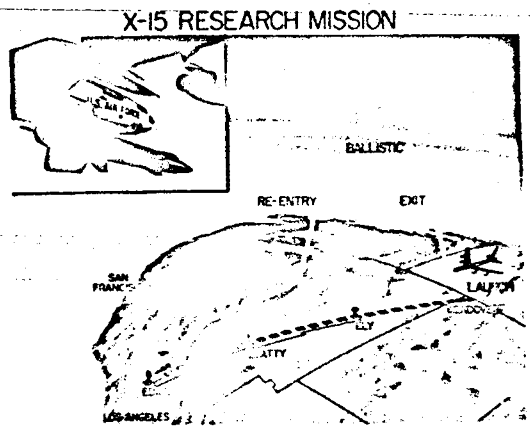

FIGURE 3

left. The launch is made several hundred miles up range; the engine is started, and the pilot pulls the aircraft into a steep climb. In less than a minute and a half, the propellants are expended, the speed is now perhaps 5500 feet per second, and the flight path follows a ballistic trajectory as the X–15 coasts up to maximum altitude and descends again toward the atmosphere. The reentry and pullout are the most critical, with maximum acceleration, maximum heating, and minimum stability and control to be surmounted before gliding back to land at Edwards.

Figure 4 is an artist's conception of the appearance of the heated structure as the X–15 passes through this critical reentry phase. As one would expect, the hottest portions (cherry red in this picture) are on the leading edges, the nose, and lower surfaces.

For a better picture of this operation, a short movie has been assembled from film clips taken during the X–15 flights. The first sequence shows an early test of the 57,000-pound-thrust engine being run in the X–15 on a ground test stand. The engine is started with the throttle

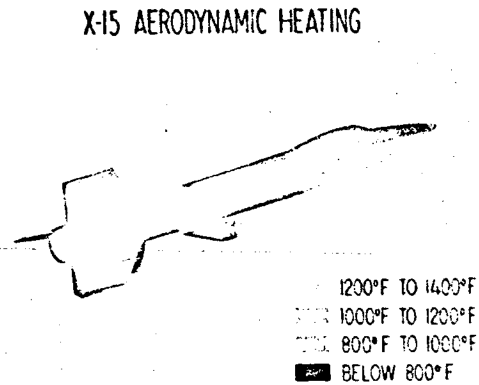

FIGURE 4

open to 50 percent of the rated thrust. . . . Note the change in the shock pattern as the throttle is advanced. The engine is now developing the full 57,000 pounds of thrust. . . . Again, the shock pattern changes as the throttle is retarded. The thrust level is now 30,000 pounds. The pilot closes the throttle and the engine shuts down. It may be restarted again if required.

The scene shifts to the 15,000-foot runway at Edwards. . . . Under the right wing of the B–52 may be seen the X–15 on this takeoff for a research mission. . . . Forty minutes later the B–52 has reached the launch altitude of 45,000 feet and is in position, several hundred miles up range, for the drop. Speed is now between 500 and 600 mph.

The following pictures of the drop are from a camera under the wing of the B–52. As the X–15 falls away from the pylon, the engine is started . . . and the chase plane moves in for a last check on the operation.

The throttle is opened and the X–15 accelerates rapidly, increasing speed nearly 40 mph each second at first, and at a rate of nearly 80 mph each second as the heavy load of propellants is burned.

These pictures are from a camera mounted behind the pilot, looking back over the tail. As the X–15 is pulled up into its climb, the vapor trails of the B–52 and the chase aircraft fall rapidly behind. . . . Note the curvature of the horizon and the dark sky above it as the top of the trajectory is reached.

The jets of steam are from the reaction controls used to orient the X-15 for its proper reentry attitude.

After the pullout, the speed brakes are opened and a turn is made toward the base. Altitude is now about 60,000 feet and speed about 1500 mph.

The lower vertical tail drops away to provide clearance for landing as the chase planes close in and the X-15 turns on final approach. . . . Speed is over 300 mph and the rate of descent about 8000 feet per minute. . . . The pilot flares out for the landing; speed is over 230 mph as the rate of descent is reduced. . . . The landing gear is extended; note the skids at the back of the airplane. . . . The touchdown speed is about 220 mph. . . . Landings have been made consistently within 2000 feet of the mark on the dry lake. Average ground distance has been from 5000 to 6000 feet. . . . The X-15 will now be checked, serviced, and mated again to the B-52 for another flight.

Upon completion of the present series of research flights, the X-15's will be used as test beds for experiments in aerodynamics, structures, new space systems, and other experiments such as the one shown in figure 5. Doors on

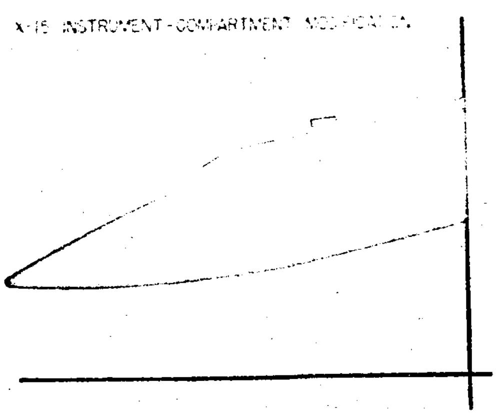

FIGURE 5

top of the instrument bay open to expose a telescope and camera for taking photographs of the Sun, planets, and stars while above the interference of the atmospheric blanket surrounding the Earth. Such observations may be made under the precise control of the pilot, and the records and equipment are returned to the ground each time so that repeated flights may be made at a relatively low cost for this type of experiment.

Figure 6 is a picture of the next step beyond the X-15. This is Dyna Soar in its launch

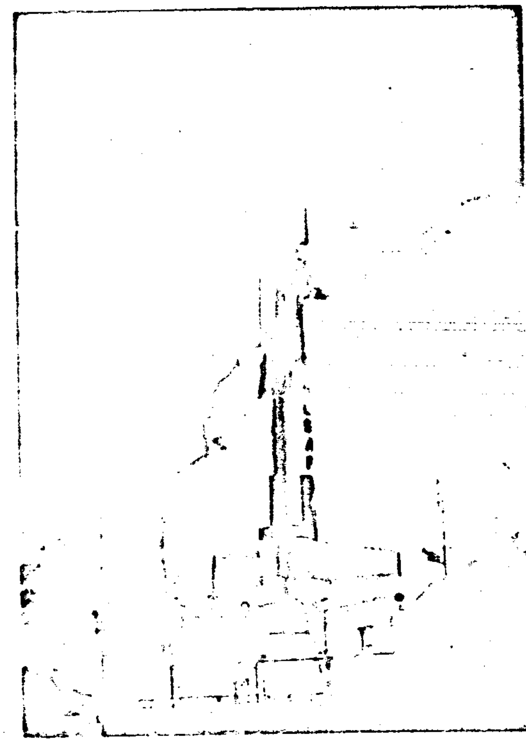

FIGURE 6

position on top of a large two-stage booster rocket. It is a highly swept, delta-wing glider weighing a bit over 10,000 pounds. Dyna Soar will offer man his first opportunity to achieve controlled, maneuverable flight at speeds approaching 18,000 mph. It will also have a limited capability to reside in orbit for short periods of time.

In figure 7 is a generalized picture of the flight regime in which Dyna Soar-like vehicles will operate. Speeds up to satellite velocities on the right and altitudes approaching 100 miles on the top are shown. At the left is the dark area to be explored by the X-15. The lower line represents the ballistic reentry, typical of Mercury, as it returns from its orbital

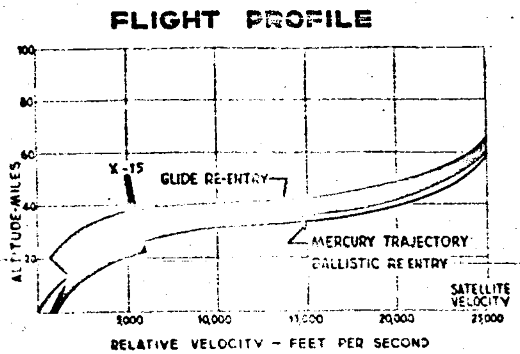

FIGURE 7

flights. The broad area is the corridor in which Dyna Soar may maneuver in its return from similar flights.

Initial Dyna Soar flights will be made from Canaveral as shown in figure 8. These flights will be to near-orbital speeds with landings on islands in the Caribbean or, as shown in this diagram, on the coast of South America. Later flights to slightly higher speeds will permit one or more orbits with landings at Edwards.

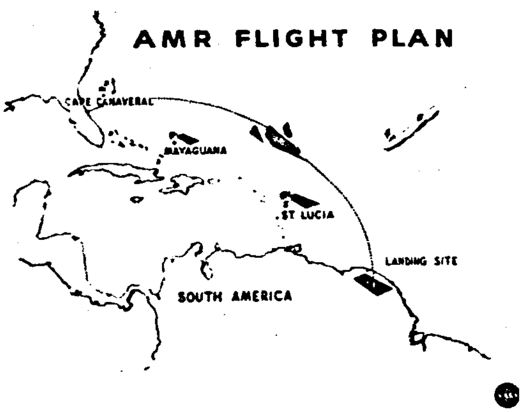

FIGURE 8

Figure 9 shows the entire launch vehicle in flight. At a relatively low altitude, the large first-stage booster separates and the second stage accelerates the glider to near-orbital speed. The second stage then drops away as shown in figure 10. Dyna Soar now starts its long reentry into the atmosphere where the pilot has a wide latitude to choose a flight path to reach any desired landing point. Figure 11 is an artist's conception of the appearance of the glider as it encounters the air molecules at these velocities; here is the most critical part

DYNA SOAR AIR VEHICLE

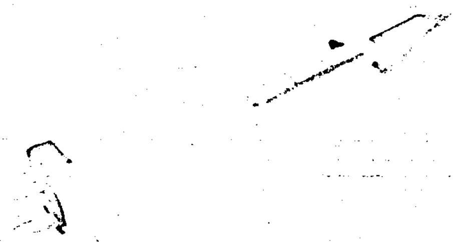

FIGURE 9

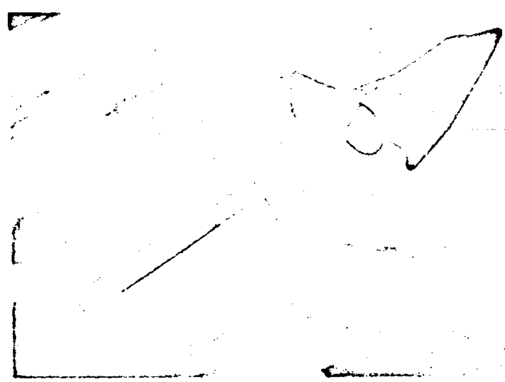

FIGURE 10

FIGURE 11

of the flight, the part in which we will derive the knowledge that Dyna Soar is designed to provide.

The X-15 and Dyna Soar are two of the many steps in the United States approach to manned space flight. These steps are very much concerned with the problems of bringing man back from space in a safe and practical manner. The advances in technology growing from these two programs and the Mercury program will provide a part of the firm foundation on which future manned spacecraft must be developed.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

2. MERCURY CAPSULE DESIGN AND DEVELOPMENT EXPERIENCE

by J. S. McDonnell*

Our company has been asked to present something on our experience with the Mercury Capsule Project. Specifically, as regards the Mercury capsule, a bit of history. Our company started work on our own initiative in November 1957. By October 1958, when Congress in its wisdom had set up the NASA, our company had expended about 40,000 creative engineering man-hours. And in February 1959, when we signed our contract with NASA, we had expended about 80,000 engineering man-hours.

What were the specific objectives? First, place a man in orbit. Second, measure crew reactions to space flight. Third, measure crew ability to perform tasks; and fourth, effect safe recovery of crew and capsule.

What are the distinguishing characteristics of this effort as compared to our work of the previous 20 years on fighter and attack airplanes? The first distinguishing characteristic was a more severe weight limitation than ever before. We were limited by the Atlas rocket with its 360,000 pounds of thrust. The capsule in orbit had to be limited to less than 2700 pounds in weight. We had hoped to use a lot of standard equipment in view of the time schedule, but as it turned out, within that weight limitation, everything had to be miniaturized.

The second distinguishing characteristic was greater safety and reliability than ever before. It was a requirement literally out of this world. And this, although I have listed it second, had the highest priority over everything. As in all major systems, we had to have at least one alternative way of accomplishing that particular purpose.

*President, McDonnell Aircraft Company.

Third, the very fast time schedule; and fourth, in our manufacturing processes was the development of a white room to keep everything in the way of hardware meticulously clean and reliable.

Millions of words have already been published concerning the Mercury capsule, and thousands of photographs. We will try to show you a little something you have not seen before. And then in our question and answer period, if time permits, we are at your service for any detailed technical questions. So, we will show first a film of about 2 minutes, showing some of the manufacturing in process. Then we will show a film of about 10 minutes. It will be an animated orbital-mission profile.

Film Narrative

"These are some of the views in the factory showing the equipment and the white room. These are views of the antenna and the fixtures. Most of this is made out of titanium, beryllium, or rhenium metal, all three of which are rather unusual in the manufacture of normal aircraft to which we have been accustomed. After having spent many hours doing the engineering to assure the design safety, the problem of translating that into actual hardware safety through the use of training and preparation of new processes was something that was a factory-wide operation.

"Here is a picture of one of the early installations in the capsule, Training particularly to do miniaturized work was one of the most important and significant steps that we had to take, with all personnel going through continuous training programs before being assigned to the project.

"Here is a picture in our white room, a

room in which we have complete humidity and temperature control and extreme dust filtering. All personnel are required to wear nylon clothing, including shoes and caps, for the purpose of keeping down any dust after we once get the capsule to the point where we are putting installations within it. Among the important things that are required are many racks of electronic test equipment. You see here many of the systems being checked out. Each system is checked out individually. Then they are checked out together, and finally, a simulated mission is run in which the capsule is put through exactly the same paces as though it were on the top of the rocket and ready for launch.

"We also developed in this period of time a good deal of miniaturization, working with printed circuit boards and plotted compounds to make all our equipment in the way of instrumentation and telemetry. Here you see some pictures of the men working at the benches in this particular condition. Here again are some shots showing the appearance. I think the important thing is not what the man is doing at this moment; it is the atmosphere, the surroundings in which he is required to perform his duties."

The next film is a home-made animated orbital-mission profile with the capsule in flight, and it will show the working of the various control systems. NASA yesterday showed a tremendously historically important film of the astronaut himself in flight and his reactions and the inside of the capsule. This will show what it looks like from outside. [Film shown.]

With this elementary, be we hope stimulating, approach, we invite technical questions during the question and answer period. I have never in my life seen an engineering and manufacturing project inspire the people working on it more. We, in effect, have on it 1200 direct space cadets. I can say from our work with NASA that the NASA people have felt the same inspiration and enthusiasm about it. It would almost seem that man had been destined to go into space, and when the right time in history came, it was inspirational to those people fortunate enough to have work to do in it.

This group at our company have been working around the clock 24 hours a day, seven days a week, 168 hours a week. Naturally, the first space cadets have been rotated, even though their leader is a practical Scotsman.

What I have seen in our little sector, plus the work done with the companies associated with us, plus the much greater work of NASA, is proof to me that the American people have great talent in this area. I believe it is fortunate that the Soviets have challenged us in this area, and I believe if the people of America want it and if their representatives in the Congress vote the money needed, that within 120 months the American people, with their allies in the free world, can not only overtake the Communist world in this area, but can far exceed them.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

3. MERCURY AND APOLLO: RESULTS AND PLANS

by Robert R. Gilruth*

The potential of space flight for extensions of man's scientific knowledge about his celestial environment, and for achievement of many advanced missions in the fields of communications, meteorology, navigation, search, and the like, are profound. It is clear that man himself must, and will, play a basic role in the advanced exploration and uses of space.

While it is true that we are now only at the fringe of the space-flight frontier, the magnitude of the job ahead is already clear. We must proceed to attack space-flight problems, therefore, with the same kind of rationality, seriousness, and dedication that has dominated our approach in aircraft development, where the risk of human life was also involved.

It is evident that launch vehicles strongly dominate our ability to perform space missions. The majority of our space accomplishments thus far have reflected our ability to convert ballistic-weapon boosters to a new and challenging service—one for which they were often not best suited. Certainly the use of modified Redstone and Atlas launch vehicles in Project Mercury has imposed severe constraints in the manned space-craft design and operation because of limitations on weight-lifting ability and reliability. Project Apollo and other advanced manned spacecraft will require large increases in launch-vehicle capabilities; and the rate of attainment of such capabilities will control the pacing of our achievements along these directions.

What is of prime importance, however, in the development of advanced boosters for future space flight programs, is a clear appreciation that man is to be a vital component of those missions. This should dictate that these launch vehicles be tailored from the start, in the most fundamental ways, to the accommodation of man and other dictates of manned missions. This will require that we face up to such challenging tasks as providing vehicles with trajectory parameters that reflect man's physiological limitations; prelaunch procedures that facilitate late insertion of man into the spacecraft; a simplification of operations that will give significant improvement in the ability to launch at a specified time; and a new high order of safety and reliability. In the latter regard, greater emphasis must be placed on the application of redundancy concepts to critical launch-vehicle components in a manner that has served eminently in the aircraft field. Detailed consideration must also be given to the use of flight-crew monitoring and control, where such measures can improve the launch-phase reliability.

As for the spacecraft itself, it is similarly clear that a broad attack on the complete frontier of applicable technologies should be the order of the day; and the problems are manifold and complex. Space presents a peculiar and hostile environment to manned-space-flight operations. Spacecraft, therefore, have their own special requirements, just as ships have for the sea, and aircraft for the air. We are only beginning to learn about spacecraft requirements. But it is already evident that, in one important respect, spacecraft can have the most difficult challenge: that of providing for satisfactory operation in space, in the air, and on the water. The Mercury capsule, for example, had to be designed for exit through the atmosphere on the booster, for operation in space, for reentry flight through the atmosphere, and for impact and survival in the high seas or on land. Some future vehicles, in addition, will be required to penetrate planetary atmospheres, and land on, and takeoff from,

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lunar or planetary surfaces. The provision of such a combination of capabilities in one vehicle will surely tax man's ingenuity to the fullest.

While some may assume that the provision of advanced launch vehicles with greatly increased weight-lifting capabilities will provide for easy, brute-force solutions to future problems, there is really little room for such hopes. Experience has shown that the desire to undertake more advanced missions will probably always place a very high premium on weight control and system sophistication.

In the development of the Mercury system, for example, the capsule configuration was basically designed for good reentry performance, while its compact, symmetrical shape was readily adaptable to the booster geometry. Its upper structure was arranged to contain the parachute systems and support their loads. The landing bag was included to attenuate ground or water impact shock, and to stabilize the capsule on the water. The problems of providing all these capabilities, together with a launch escape method, separation motors, retrorockets, life-support equipment, stabilization and control systems, communication gear, and other crew requirements within the allowable weight limits, was extremely challenging. If the Mercury capsule were to be redesigned today, there is very little in its basic concepts that we would or could change.

In the development of Apollo concepts, we again face a weight-limitation problem that forces us to take a hard look at the primary objectives to determine, in a rational manner, what compromises must be made. It is again clear that we cannot permit old concepts to dominate the configuration design, unless they can pay their way in the accomplishment of the basic space mission. Regardless of how we examine the problem, the conclusion remains, that, within the dictates of practicability, safety, and reliability, the maximum performance and operational capabilities in space are the real fundamental requirements to which other desires must be subservient.

The Apollo design must therefore cater to the maximum of space-mission capability, incorporating only an optimum configuration compromise for launch, reentry, and landing requirements. We therefore are compelled to relegate conventional landing capabilities to a lesser importance, unless they can be provided with little penalty to overall mission performance.

One concept that offers promise for the controlled landing of spacecraft is the Rogallo "Flexiwing" or paraglider. With this device, which is basically a stowable wing of the same order of weight as a parachute system, it may be possible to utilize an optimum configuration for the space and reentry operations, and still provide a horizontal pilot-controlled landing capability on the ground or at sea. Such a wing, with a lift-to-drag ratio of about 5, could be deployed after the reentry maneuver has been completed, to permit final selection of the landing area.

Intensive research and development efforts in a wide variety of such fields are accordingly necessary for maximizing space-flight capabilities within allowable weight limits. It is obvious that there is an open field for the evolution of a whole host of new concepts and techniques to speed us toward our long-range objectives.

The space-flight program objectives themselves need to be most carefully selected. Each of two extremes should be avoided. The selection of complex projects that achieve only a small improvement in space capabilities are prone to early obsolescence, and dissipate too much of our manpower and financial resources. On the other hand, the selection of project goals that require technological advances far beyond those that are clearly within the realm of concerted development effort can long delay the availability of useful improvements in space capabilities, or even defeat practical accomplishment of the project in a timely manner.

In meeting our national needs, our space-flight programs should strive for a middle course. While each step should be sufficiently large to tax our ingenuity to the utmost without predicating success on a technological breakthrough, the projects should be devised with sufficient scope and flexibility that we may capitalize on the ensuing technical and scientific growth and thereby facilitate timely and efficient advances in our space-flight capabilities.

The goal set of manned lunar landing is one of the most difficult tasks that could be chosen. For this reason the Apollo program will be taken in progressive steps. As an initial step, the Apollo vehicle should provide a significant advance over Mercury for Earth-orbital operations. We expect that the incorporation of a larger crew, the extended mission duration, the maneuverability capabilities, and accommodations for special-purpose equipment, will provide for immediate conduct of a wide variety of scientific, technological, and special civilian services.

At a later date, when the erection of large manned permanent space stations in orbit may be undertaken, the Apollo vehicle could serve eminently in the construction and supply of such a station. The Apollo vehicle itself will also act as a test bed for the orbital development and qualification of techniques and hardware for manned lunar missions. As the growth of technology permits, the Apollo spacecraft would then form the nucleus of a manned circumlunar and lunar-orbiting vehicle for scientific observations of the Earth-Moon system. Further extensions of the Apollo capabilities to permit actual manned lunar landing, exploration, and return, would then be undertaken.

In the conduct of this nation's space-flight program there is much to be done and much to be learned. In any advanced project, it is expected that mistakes will be made. This is a natural part of the business of learning. What is vitally important to our moving ahead in a mature fashion, however, is that we not make the same mistakes twice. In the complex operations with booster and space-vehicle projects, we must take appropriate steps to share the detailed lessons of their successes and failures. There is a wealth of valuable experience that could do much to increase the pace and success of the national space-flight program if it could be ferreted from the unreported recesses of our many projects and effectively disseminated to other project groups. This is not to suggest that there has been a willful withholding of such information, or to pretend that project personnel are not already overburdened with the primary tasks of sweating out each day's direct project problems. It is felt, however, that many of these problems might be alleviated, if each man could share the benefits of the sweat of others who had already labored through a similar problem, and thereby gain the time to pass his new experiences on to others. On the other hand, a flood of additional documents beyond the deluge which already exists, does not seem to be the right answer.

Perhaps what is really needed, as a start, is a mechanism similar to that employed in the aircraft field, for specifying the detailed design requirements that have been learned through our past experience, and is kept up to date as additional knowledge is acquired. This might be a space counterpart to the old handbook of instructions for aircraft designers. A skillful and adequate group of specialists working full time on such an activity is badly needed, and could pay rich rewards in the progressing of the nation's space-flight programs. Much room exists for invention of more effective methods for interchange of vital experience, and the problem should be attacked with a real sense of urgency.

In summary, I would like to highlight the following needs of our space-flight programs:

First, the aggressive development of large launch vehicles that are specifically tailored to the requirements of advanced manned space-flight programs. Aircraft experience in flightworthiness requirements and techniques should be exploited here.

Second, the intensification of research and development efforts on the whole range of technological problems confronting rapid growth of manned-space-flight capabilities, with special emphasis on the evolution of new concepts and techniques that will minimize compromises dictated by the need for operation in the full spectrum of environmental media.

Third, the selection of goals for space missions that give us a large and rapid reward for our investments, with emphasis on designs that maximize performance and operational capabilities in space, and that can capitalize on breakthroughs when and where they occur.

Fourth, a vigorous attack on practical methods for the pooling of space-flight design, development, construction, and operational experience for the mutual benefit of all programs.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

4. PHYSIOLOGICAL PROBLEMS OF MAN IN SPACE

by W. RANDOLPH LOVELACE, II*

INTRODUCTION

The Administrator of the National Aeronautics and Space Administration, James E. Webb, recently outlined the objectives of this nation's space program over the next few years. He envisioned such things as determination of the environmental conditions in space; a continuation of the man-in-space research program including orbital flights around the Earth, manned space stations, followed eventually by lunar and interplanetary exploration; operation of a world-wide system of weather and communication satellites; the development of new power sources, including nuclear, for use in space; detection of the existence of life on other planets; and a better understanding of the origins of the solar system and the universe.

Furthermore, the Director recently determined that more than 5000 companies and research organizations are now engaged in work connected with space, and this effort has produced more than 3200 space-related products. Incidentally, many of these new products can be applied to development of supersonic commercial transport aircraft.

The score card of the United States' missions in space as of May 17, 1961, is a most impressive one, but the published scientific results of these flights are far more impressive. The Soviets have not made public the results of their highly significant manned orbital flight.

Earth orbit	US	39
	USSR	12
Solar orbit	US	2
	USSR	2
Lunar impact	USSR	1

In the 1959 Killian report on "Strengthening American Science," a particularly pertinent conclusion was that "one of the dearest lessons to emerge from the history of medicine is that various scientific disciplines, seemingly unrelated, have a way of stimulating and fructifying each other in an unexpected manner. This complex back and forth interplay is the life and soul of science and technology. There can never be too much of it." This conclusion is being proved daily in research in aerospace medicine.

Successful implementation of the man-in-space research program requires close association of scientists who are physically, biologically, and medically oriented. They can solve problems of common scientific interest at the basic research level. In turn, this information can be disseminated to those concerned with the crew's personal equipment and to those responsible for the design and construction of manned space vehicles.

A recent statement of policy of the Office of Life Science Programs of the NASA follows:

"Utilization of modified Mercury capsules, the global-tracking network, and operational experience for a program of four in-flight experiments of two, six, ten and fourteen days' duration is proposed in order to appropriately extend the time scale and provide continuity of research effort consonant with technological advances. Proper attention to

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scientific merit and validity, as it relates to the broadest aspects of life sciences research for future earthbound benefits, is emphasized."

To accomplish the objectives of the National Aeronautics and Space Administration, Dr. L. V. Berkner, Chairman of the Space Science Board of the National Academy of Sciences, has recommended broad and extensive participation by universities and research institutions throughout the nation on fundamental research in space.

This presentation is concerned with some of the areas where research is needed.

EDUCATION

In addition to utilizing to maximum effectiveness the present scientific manpower in the United States, an accelerated program is essential to develop more outstanding space-oriented scientists with originality and imagination.

James V. Conant and his associates found that only about half of the students that could benefit from advanced education are receiving it in this country. In addition, it is not a part of our culture and tradition, as it is in Russia, to use women effectively for creative careers in research. Every young individual who has the desire and capacity to become a scientist should be given a proper education to lead toward this achievement.

The post-graduate training program for flight surgeons and life scientists and technicians at Harvard, Ohio State, and other interested educational institutions should be doubled. During the course of such training these men will be exposed to and often participate in experiments connected with space.

CLINICAL AND LABORATORY EXAMINATIONS

For the past twelve years the Lovelace Foundation has had underway the development of a program of special examination and evaluation procedures for the determination of the state of the physical, mental, and social well being of preselected and highly experienced and intelligent pilots and their crews. The long range objective of this program has been to ascertain whether or not a particular space crew member has the capacity to live, observe, and do optimal work in the environment of space, as well as serve as an experimental subject and return safely to Earth. It has been the considered judgment of aerospace medical scientists that man can contribute scientific judgment and discretion in conducting scientific exploration of t[illegible]ts that can never be fully supplied by his instruments, however complex and sophisticated they may become. In contrast to clinical medicine, where the stressing agent on the body is disease, in aerospace medicine the stressing agent on the normal subject is the environment. This combined examination and selection program under the direction of the NASA was a joint effort by the Foundation; the Army, Navy, and Air Force; the Atomic Energy Commission; the National Institutes of Health; and the NASA Space Task Group. The success of the program is attested to by the performance of Commander Shepard and his associates.

As far as can be ascertained, there has been no previous occasion when such a highly selected and technically capable group of men as the astronauts had such extensive clinical, laboratory, roentgenologic, physiologic, psychologic, and anthropometric evaluation. The combination of these disciplines, used in the examinations and selection of the astronauts, and the establishment of new and improved criteria will be required in the future selection of space crews, including highly experienced pilots, physical and life scientists and technicians.

Research is also required on the effects of the stresses of the space environment on individuals with various illnesses and injuries that normally occur in a certain percentage of the population over a long period of time such as would elapse on an interplanetary mission, or on assignment to a space or lunar station.

The results of the tremendous research effort in the life sciences and the concomitant development of new techniques and equipment in space will alter radically the present procedures used in the diagnosis and treatment of patients, thus again demonstrating that science serves the world by serving humanity.

BEHAVIORAL PROBLEMS

During World War II the Air Force conducted an extensive research program on the determination of the qualities of leadership and teamwork that produced outstanding bomber crews. This research on air crews and simultaneously on submarine crews by the Navy has continued with excellent applied results, as exemplified by the recent 60-day underwater nuclear-submarine cruise, where the crew lived and worked in very close quarters harmoniously and with an absolute minimum of behavior difficulty or emotional instability. Further research will be required to select crews of three and more to participate in space flights lasting from a few hours to much longer periods of time. There will be need for manning permanent space stations and lunar bases.

STRESS

An accelerated research program on an international basis is needed to establish the effect of single as well as the combined stresses in space with respect to the following thresholds of performance degradation in man, namely:

(1) Degradation from fine performance

(2) Gross degradation

(3) Gross degradation with reversible tissue damage

(4) Short- and long-time degradation with irreversible tissue damage.

Naturally, every possible precaution will be taken by the use of protective measures and equipment to avoid irreversible tissue damage. Insofar as possible, such research should be done in laboratories on Earth.

Acquisition of as much scientific information as possible should be accomplished in Earth-based laboratories and by the use of balloons and rockets prior to spacecraft missions. This is the most economical and satisfactory method. Information from such programs generally helps in developing or improving and calibrating scientific equipment to be carried aboard spacecraft, and in interpreting the data derived from space experiments. For example, radiation cannot be seen, felt, or heard, but there are excellent detection devices; and early warning schemes and adequate shielding can give protection. Prediction of solar flares would be most helpful. Eventually, of course, there will be orbiting space stations for the exposure of space crews to the environment of space, the conduct of experiments, and training programs, including rendezvous. Establishment of permanent lunar bases will provide for an extensive training and research program.

The effect of combined stresses such as heat, rotation, oscillation, vibration, and acceleration, including changing from weightlessness to positive g, requires research to determine whether the degradation is additive, what the cumulative effect is, and what the effect is on the various systems of the body, particularly those that have to do with the interpretation of displays and the use of controls. Eventually, when vehicles such as Dyna Soar are capable of aerodynamically efficient flight, the pilot, within certain limits, can vary the physiological stresses he and his crew are undergoing, and will have very good control of his landing site.

As part of the selection program for space crews, their tolerance to single and multiple combined stresses must be ascertained on an individual basis.

NUCLEAR PROPULSION

The future of nuclear propulsion for spacecraft is so promising with respect to the reduction in the weight and size of boosters and the amount of thrust available that a large effort is being expended in research on shielding of the crew. In space, only shadow shielding is needed. If shielding of spacecraft is required to protect the crews from natural radiation in space, including solar flares, then nuclear propulsion becomes even more attractive.

SAFETY AND RELIABILITY

The farther man goes away from Earth, the more difficult it is to ensure his safe existence and return. He must live and work in a pressurized space vehicle in which oxygen, food, and other requirements, and means for the absorption of carbon dioxide are provided, as well as protection against radiation in space. On Earth the atmosphere serves as a protective shield.

As time goes on and lunar landings are made, special space suits will be required for exploration on the surface of the Moon and the other planets. The longer the mission, the greater the requirement for vehicular reliability.

Research is under way on the basic causes of human error with or without stress, the development of hazard and reliability criteria for the space vehicle and its components on a total system basis, and the development of protective and emergency equipment.

Standby crews and vehicles will be available in the future to go to the rescue of space crews in case of an emergency.

WOMEN AS SPACE CREW MEMBERS

Privately financed studies are under way at the Lovelace Foundation for Medical Education and Research on the examination and evaluation of approximately 20 highly experienced and motivated women pilots, who volunteered as potential members of future space crews. The success of the WASP program in World War II and the outstanding record of many women pilots since then has made us confident that women would eventually participate in some capacity in space flights.

These women are undergoing essentially the same detailed and comprehensive physical examination, laboratory tests, X-ray examination, and physical competence tests as the male astronauts had. In time it is anticipated that those that pass this test program will have stress tests such as exposure to heat, cold, noise, altitude, and acceleration. The final results of these tests on women will be published, thus making available the data in the medical literature.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

5. LAUNCH-VEHICLE CONSIDERATIONS FOR MANNED SPACE FLIGHT

by JAMES R. DEMPSEY*

The subject of "Launch-Vehicle Considerations for Manned Space Flight" is a particularly timely one for several reasons. Recently Major Gagarin and Commander Shepard have made successful flights. There will be more flights soon. The Air Force's Dyna Soar, a manned orbital glider, is approaching its test phase, and the nation is entering into the development of very large boosters, many of which will undoubtedly carry manned payloads.

The launchings that have already taken place and those scheduled for the near future, are all dependent on the booster technology developed for the ballistic missile program. We find ourselves almost constantly faced with answering the question of the adequacy of such boost vehicles in manned operations. We also ask ourselves how would boosters be different if we were designing them purely for manned payloads.

There are some very basic factors that must first be established, and having established them, I believe that the answers to our questions drop out in a surprisingly simple fashion.

First, and very obviously, the job of a space booster is to deliver a payload into an orbit around the Earth, on a trajectory to the Moon, or onto a path toward a planet. Whether the payload contains a man or not, the booster is assigned the job of imparting to that payload a velocity sufficient to accomplish a mission. One of the tasks of the booster designer, then, is to make certain that the booster utilizes propellants efficiently in order to keep sizes and costs to some reasonable level consistent with accomplishing the mission.

Our technology has evolved to the point where we have developed reasonably efficient design philosophies in propellant utilization and booster structures in terms of thrust-to-weight ratios, mass fractions, booster staging, and reduction of velocity losses due to gravity and drag. These design philosophies, which are now engineering principles, have resulted in the kind of booster we have today, a type that imparts its velocity to the payload at very high acceleration rates.

And here we begin to see the direction in which we are heading when we introduce man into the picture. Because the booster is an extremely high-performance system operating in support of a very precise mission, the booster must of necessity be under automatic control. Man simply cannot react quickly enough. Granted, we could consider slowing down the booster operation to a point where man could actually control the flight. This, however, would result in completely unacceptable propulsion efficiencies. The conclusion, then, is that man is not going to be used in the control loop of a booster. The implication here is great. If these conclusions are true, then there is no need to modify the basic philosophies of booster design to change such things as acceleration, noise, vibration, and other stresses. There is no need to change the basic control philosophies that permit man to be nothing more than a passenger during boost.

Thus, except for the job of protecting this very valuable piece of cargo, the current basic design philosophy of rocket-propelled booster vehicles is already nearly adequate and sufficient.

Now, what about passenger protection? Here

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again we find that we are already on the right track and already accomplishing some of the things we would choose to do if we had a completely free hand to start from scratch. There are exceptions, of course, but our principal concern is not with basic booster design philosophy, but rather with considerations of safety, reliability, and escape. These considerations are, for the most part, peripheral to the basic booster vehicle.

We should be concerned primarily with safety, of course. In the past in the aircraft industry, we have generally used a 1.5 safety factor in the design of aircraft. This means we calculate the maximum stresses that are likely to occur in the aircraft; design the wings, fuselage, and control surfaces to withstand those stresses, and then add on 50 percent more strength in metal as insurance. In the ballistic-missle business, since ballistic missles were not designed to carry people, we reduce this safety factor to 25 percent. The principal purposes of the safety factor in the missile are to permit its use under any weather or wind condition and to provide some insurance in the event of an inadvertent structural weakness.

We should remember that safety factor means metal, metal means weight, and more weight means either less payload or more booster. For the condition where the payload weight is constant, a higher safety factor means a larger booster for the same payload, and consequently more cost.

So on the basis of pure economies, we ask ourselves whether the additional safety factor, by itself, is worth the extra dollars.

Let's take this discussion a step further. We can agree that the reason for a high safety factor is space-crew protection. Another point: Our booster will be used for manned payloads some of the time and for instrumental payloads at other times. If this safety factor in a new booster costs us, say, 5000 pounds of payload, it costs us 5000 pounds whether the payload is manned or not. So, we are penalizing unmanned launchings by using a safety factor required only when the system is manned. And again, this weight penalty shows up in dollars too.

If we can take this 5000 pounds and put it into safety equipment that applies only when the booster is launching a manned payload, then we've accomplished some very significant economies in space booster utilization. This is precisely what is already being done in the utilization of the Atlas for boosting Mercury, the Titan for boosting Dyna Soar, and in the forthcoming Saturn for boosting NASA's Apollo.

We can proceed somewhat further along the same line of discussion. In our hypothetical boosters, we have said that 5000 pounds is what extra safety for manned flight costs us. We can put it into the basic booster vehicle, so that it is aboard on every flight and penalizes us when we *don't* need it. Or we can use it in such a way that it's available to us only when we have a man in the payload. We should realize, of course, that in neither case does this weight significantly improve our capability of accomplishing the booster mission. All it does is improve the survival chances of the crew.

There are actually better ways to utilize this weight in ensuring crew survival. These include the use of redundant systems, particularly in the electronic areas; crew escape systems, in the event of an abort requirement; and fins for additional stability and control, in the case of winged payloads. Having developed the means for introducing these at will into what is evolving as a "conventional" rocket booster, we have in effect the best of both worlds. Thus, we have an efficient booster for unmanned payloads and a safe booster—one that ensures crew survival—when our payload is manned.

There are, of course, other considerations to which we must give attention when considering the man. Again these are, to some extent, already being handled in boosting manned payloads with our current launch vehicles. First, we must be able to provide the man some control over his own destiny. The crew must be given the opportunity to override the control and abort network in the booster if, in their judgment, an automatic system is not functioning properly. We have already pointed out that in the high-performance, highly precise booster, events occur too quickly to give the man primary control. However, no automatic system can be made 100 percent reliable. A commercial airliner, or your new '61 Thunderbird, will fail occasionally.

It is certainly clear that complete dependence should not be placed in the automatic system, particularly where crew safety is concerned. Override has value here in terms of crew safety as well as for psychological reasons.

Another factor that should receive our attention, particularly when we think of manned operations as a routine thing, concerns the booster system, the payload and the ground support for both. We know the effect of delays and holds in the countdown for Commander Shepard's Mercury flight. On two occasions he was confined to the capsule for several hours while handling crews made repairs on the booster. Some delay in countdown may continue to be an unavoidable nuisance, the situation improving with our knowledge, but it will not be completely eliminated even when we reach reasonably high degrees of system reliability. What I'm driving at here is that, when we are considering this problem of space boosters for manned operations, we have to give due thought to more than just the booster itself. Crew safety, crew survival, and smooth operations dictate that we give adequate thought also to such mundane and unglamorous things as ground handling, ground operations, and smoothing out our countdown functions and our checkout procedures. All of these become important as soon as we introduce a man into the routine.

Finally, being a part of General Dynamics, I feel I should briefly mention the more advanced concepts in booster technology that we in Convair have been developing for well over a year and a half. One of these concepts employs a winged space vehicle that uses the principle of "single-stage-to-orbit." This concept employs a horizontal takeoff and landing configuration, a truly advanced recoverable booster. Here we consider a crew in the more accepted sense of the word, a crew almost as it exists in a current high-performance aircraft. Here the crew is something more than a passenger during boost. In this concept, the crew member controls the vehicle at takeoff from a runway, probably turning the flight system to automatic control for the trajectory-to-orbit phase of the flight. Later he takes control again to assist the automatic system in rendezvous with a satellite or space station. He would also have control for recovery and landing. There is not much question that, in this new kind of booster operation, we have much to learn about crew performance and crew protection. We can anticipate that this new kind of system will present some problems in manned operations that are completely novel and some that may not be. From now until the system is operational in the early 70's, we must learn to adapt the system to its crew and to train a crew to operate in a completely new vehicle environment.

And so we progress, from our work today in boosting man into orbit, to the next generation of advanced rocket vehicles of the 70's where, we suspect, our crew may once again be in active control of the booster system.

PRESENT AND FUTURE OF MANNED SPACE FLIGHT

6. FUTURE SPACE MISSIONS

by MAJ. GEN. O. J. RITLAND*

About five years ago a certain color advertisement appeared in one of the aviation trade publications. It pictured a view from the Moon, and the caption read: "There's a beautiful Earth out tonight."

That same year a Los Angeles newspaper quoted a Moscow radio broadcast which stated that the Soviets believed a rocket to the Moon could become practical in the next five to ten years.

As recent history has shown, the Soviet prediction was accurate. As for the magazine ad, no one has yet seen the Earth from the Moon, but there is every reason to believe that someone will and probably before this decade has ended.

In discussing future space missions, I intend to indicate the kind of capabilities we must add to our national space aptitude. I will review briefly where we stand today, and then outline a few of the broad objectives we seek in our applications of space.

Much has been said and done about space in recent years, so much, in fact, that perhaps our perspective has become a bit clouded. First of all, I think it is important for us to recognize and accept that space is a place where things can be done. And at this exciting juncture in time it is the new frontier of opportunity, waiting to be employed by the mind-stretching talents of man. The ultimate significance of space will be determined by the use man makes of it.

We in the Air Force are engaged with the National Aeronautics and Space Administration and with the other military services in a partnership approach, aimed at realizing in space those scientific and military missions that will safeguard our democracy and benefit civilization. We are all motivated by a sense of urgency, for we recognize full well our obligations to the security of the United States which—in this day and age—demands unqualified leadership on the Earth and beyond it.

The progress we have recorded in the past three years has been nothing short of remarkable. We could not have orbited 41 space vehicles successfully, nor launched 167 ballistic missiles, nor placed satellites in orbit and recovered capsules from them—if we as a nation had not first put together a vast and versatile package of skills and talents, resources and facilities, dedicated to the exploration and productive use of space.

However, in spite of these rapid strides, we must realize that we are still in a state of infancy in the space age. Our position is similar to the attitude we held toward the airplane in 1910. At that time a few far-sighted people conceded that it might someday be practical for man to fly, but even so eminent an authority as the magazine "Scientific American" looked upon aircraft with disdain.

"To affirm that the airplane is going to revolutionize the future is to be guilty of the wildest exaggeration," that magazine reported editorially.

Such an assessment probably was valid in terms of 1910 technology, but it did not allow for the technological developments to come. The dynamic progress of aeronautical sciences and skills in the last half century has not only carried us from the Jenny to the jet, but has brought us also from Kitty Hawk to Canaveral. The lesson of modern history teaches that we dare not be shortsighted *now* in our look toward space.

In 1956 the Assistant Secretary of Defense

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for Research and Development said a rocket vehicle capable of circumnavigating the Moon would probably be the next step after Project Vanguard. This forecast, while attainable, hurdled the multitude of problems that had to be solved before we could hope to attain a physical dexterity in space.

How well we have overcome many of these problems and turned stumbling blocks into stepping stones is illustrated by the advances of the last half-dozen years. In the early 50's the X-1 was exceeding 800 mph. Later, the X-2 soared to 100,000 feet and passed 1900 mph. But with our first intercontinental-ballistic-missile flight in 1958 we sent a man-made device to an altitude of 500 miles and reached a speed of 12,000 mph. A satellite in orbit 300 miles above the Earth travels at 17,000 mph.

Such accomplishments required quantum jumps along the whole spectrum of technology. Projectile velocities, for instance, which had been largely limited to about 3000 to 4000 feet per second, were accelerated to 25,000 feet per second. Solving the reentry problem meant penetration of the thermal thicket. Advances in guidance systems, propellants, and metallurgy had to be mated with increased knowledge and experience in the effects of radiation and with mechanical and electronic characteristics. Management, production, communications, tracking facilities, and ground-support equipment had to be geared to new and demanding standards. The consequent result has been the forging of a substantial base for space.

We are now deep in the process of defining and fulfilling the missions to be accomplished in the development of a national space program. These missions, whether they may be military or scientific, must be in the best interests of our country. The stature of our capabilities today cannot be measured by any one program or any single requirement. Getting to our position today necessitated a striking increase in our fundamental space capabilities. To get where we want to go tomorrow will demand another order-of-magnitude increase in the technologies that stretch from here to infinity.

We can achieve designated space goals because we have the proven ability. But to be vital and effective, our total space program, I think we all will agree, must have clearcut national objectives planned according to realistic and stringent time schedules. It must point toward attainments that will accrue to the United States the admiration of the world and that will stimulate the imaginations of peoples everywhere.

There are a number of pressing requirements facing us in the fulfillment of these broad objectives. In the first place, it is essential that we increase our booster capabilities. As you well know, work is progressing in this direction with the NASA Saturn vehicle, with the F-1 engine, and with follow-on booster studies now under way. As Mr. Dempsey has indicated, greater weight-lifting capabilities are essential for manned scientific vehicles. But we in the Air Force have an equal interest in more potent boosters, particularly if we are to perform such feats as sending technicians into space to maintain, resupply, and repair satellites.

This actually appears to be a requirement worthy of consideration. To be successful, of course, such a program demands a proven rendezvous capability in the dimension of space.

To satisfy the military responsibilities of our national space program, it is essential that we launch comparatively large numbers of satellites into precise orbits and that we replace them from time to time if repair is not feasible. The Midas satellite system, for instance, on which we will soon depend for early warning, and global communications both demand multiple satellites. To fulfill these requirements, we see a need for boosters that can launch space payloads in routine fashion at relatively low cost, and that are as simple and reliable as possible.

As a second requirement for our national space objectives, we need to develop our overall capability to recover objects from orbit and from deep space. Specifically, it is imperative that we improve our index of reliability, that we develop maneuverable vehicles capable of airplane-type landings at predesignated points, and that we enhance our ability to recover at high speeds. It must be remembered that little or no data are available above the ballistic-missile reentry speeds, and only flight-test programs can provide reliable data in this area. A manned lunar vehicle proposed for use in the later years of this decade by NASA, for example, will attain speeds of Mach 37 and will be designed to survive the higher reentry velocities that such speed dictates.

In the third place, we must step up our programs of applied research.

Looking back ten years we can recognize that in 1951 we didn't have the thermonuclear weapons, we didn't know about the Van Allen belts, we didn't have adequate inertial guidance, we didn't have large-thrust rocket engines sufficient to power an ICBM, and we didn't have transistorized equipment. These advances were made in part because of applied research conducted in the 50's. It is apparent that our capabilities in 1971 will depend in large measure on the applied research programs initiated or under way today. As Air Force Secretary Zuckert has said, "For every system in the inventory, we need one in development and a third in the idea stage."

The breakthroughs of immediate history point to the breakthroughs of the instant future. The real value in getting to the Moon lies in the resultant capabilities that such an accomplishment entails. When we send a man on a lunar mission we will be demonstrating that man is ready and able to take his place in space—that his unsurpassed evaluating, reasoning, interpreting, and reacting abilities will be brought to bear on the perplexities of the space environment. Man's exploration and eventual occupation of the Moon will require technical advancements which will greatly expand this nation's fundamental space knowledge. It will be an ideal proving ground for demonstrating man's capacity to function in space and to carry out operational techniques such as navigating, communicating, refueling, assembling, and docking.

Needless to say, a host of demands face us before we venture toward the Moon. Yet we are busy solving these problems in the course of the Mercury program and in many of our Air Force programs, such as Discoverer and Dyna Soar. In the Mercury project, for instance, the United States has had to develop a lightweight flight capsule capable of sustaining life, that can be controlled, and that assures safe reentry. Reliability requirements have been stressed to the *n*th degree.

Greater reliability in our capacity to inject satellites into orbit, command and control them on orbit, and to direct them to perform electronic services in space is being proven through the Discoverer program which—not incidentally—is also yielding useful scientific information.

One area in which further intensive study is needed is that of bioastronautics. Extrapolation from current biomedical knowledge plus ground-based simulation can provide reasonable answers for low-altitude orbital flights of 24-hour duration. Beyond this, however, it appears that it will be necessary to carry out a series of experiments in space vehicles to get answers to such urgent problems as ambient radiation shielding requirements and tolerance limits for weightlessness.

In our quest for broader understanding of the space frontier we are seeking to gain a foothold in a new environment. At the same time we hope to establish the United States in the eyes of the world as a leader in the technologies and the applications of space. Military people traditionally have participated and frequently pioneered in the great and difficult explorations of our time, and the role of the military in the unfolding of space is no different—but it is *more urgent*.

In learning about space we are sending satellites aloft for a variety of purposes. Our nation needs information satellites, early-warning satellites, communications satellies, weather satellites, and navigation satellies. We must develop intraspace rendezvous and transportation capabilities. Most significantly, we must safeguard our freedom, for only in freedom and security can we be at liberty to evoke from space the potentials that exist there for man's future welfare and progress.

When we have translated all these aspirations into reality, when we have traveled to the Moon and gazed upon the universe from that vantage point in space, I hope that we may look upon our globe and be able to say: "There's a peaceful Earth out tonight . . . and it is beautiful indeed."

SCIENCE IN SPACE

ADDRESS BY LLOYD V. BERKNER

SCIENCE IN SPACE

by LLOYD V. BERKNER*

The opportunity to speak today in the company of so many space leaders is a real honor and pleasure. In particular, I would pay my respects to Mr. Webb, the Space Administrator, and to Senator Kerr and his associates in the Senate and the House whose untiring efforts are devoted to giving us the most distinguished possible space program.

One gets a little tired these days of reading about Russian space supremacy. To get this matter in focus, I will discuss today one aspect of space effort in which the United States has the clear lead, and in which the United States can keep that lead with properly designed effort. That is science in space. Since, as space activity becomes more difficult and advanced, the space effort will be limited by our knowledge of space at any time, leadership in space science must soon become one of the controlling factors in acquiring space leadership generally. Consequently, we of the Space Science Board of the the National Academy of Sciences, in advising the government on behalf of U.S. science, try to look at every future eventuality to be sure that any lack of knowledge of space at any time in the future will not stand in the way of a distinguished accomplishment. In this we have had the support of the Congress. I feel confident that those additional measures that the Space Science Board has recommended will receive early support of the whole Government.

Our activities in space really break down into three categories:

(1) Science in space
(2) Space applications
(3) Exploration of the Moon and planets

Clearly, in science in space and in space applications, the United States has won clear leadership. Only in the first steps toward space exploration have the Russians shown superiority, largely because of their success in the weight-lifting contest. But in the contests ahead, success requires far more than mere weight-lifting capability; indeed, success will require superiority in every department.

As an aside, we might comment that the Russian superiority in weight lifting arose from their decision in 1952, a decision that we did not make until four years later. So, in space, the laurels go to those with foresight and vision. Therefore, we must seriously inquire now whether there are decisions that we should be making now that will affect our standing five or ten years hence. Concerning science, it is here that the Space Science Board can be of maximum aid to our Government.

But in the meantime, we should not sell our accomplishments short. Let us stop for a moment to review the accomplishments of the U.S. space probe, Pioneer V, which was launched more than a year ago, and which still holds the communication distance record of more than 20,000,000 miles.

As Pioneer V left the Earth, it passed through the two strongly ionized belts of radiation encompassing the Earth, known as the Van Allen Radiation Belts after their discovery by Professor Van Allen in the first Explorer satellites only a year or so earlier. As Pioneer V reached the 40-thousand-mile mark, it discovered a third immense ring current that surrounds the Earth 8 to 10 Earth radii away. It found that some 10 Earth radii away, the Earth's magnetic field is bounded by the plasmas of space, and it discovered an interplanetary field that seems to permeate our planetary system—a magnetic field having a strength of a little less than one one-hundredth of 1 percent of the Earth's geomagnetic field at the surface. This field, however small, repre-

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sents very large energy potentials, since it permeates the vastness of interplanetary space. Moreover, it is of immense scientific importance in understanding the interaction of the Sun on the Earth. When the rocket reached the 6-million-mile mark, the Sun erupted violently. In a few hours, Pioneer V radioed the message that it had encountered the cloud of particles that had been ejected from the Sun, particles whose later encounter with the Earth produced a geomagnetic storm. Associated with this cloud, the space probe found a sharp increase in the magnetic field in the cloud to some 20 times the undisturbed space value, showing that the particle cloud from the Sun was a plasma traveling at high velocity in which was imbedded a strong magnetic field. Soon afterwards, the interplanetary spacecraft noted a marked decrease in cosmic-ray intensity, similar to the so-called "Forbush" decreases, which are often observed on the Earth at the time of strong geomagnetic disturbances. Previously it had been thought that these Forbush decreases were caused by distortion of the Earth's geomagnetic field. But this observation by the space vehicle demonstrated that the Forbush decreases in the cosmic-ray intensity are not geocentric, but probably characteristic of the whole of the planetary system.

I mention this series of discoveries from a single rocket probe to illustrate the powerful character of the knowledge that is derived from space exploration. I venture to say that no theoretical speculation in the absence of such experiments could possibly predict the facts of space as we are now finding them. Just a few weeks ago, a space probe out to 160,000 miles showed remarkably strong magnetic fields at those distances and raised a whole new series of questions concerning the environment of the Earth.

The importance of space research lies not just in the simple facts that it provides: more especially, it is in the power and quality of these facts, in juxtaposition with our more routine observations from the Earth's surface, that gives us the coherent and orderly description of the main events of our planetary system, and of the sequence of reactions initiated by the Sun on our Earth.

Let me try to sketch out the fascinating picture that is now emerging from our IGY studies of interplanetary phenomena made on Earth and in space. From time to time, the Sun's atmosphere—its chromosphere—becomes spotty and turbulent. About every 11 years these turbulent vortices, known as sunspots, reach a maximum in number and area, mainly in one hemisphere. As the sunspot cycle progresses, the spots appear closer to the Sun's equator, as they gradually diminish in number and intensity, until there are no sunspots at all at sunspot minimum. But then these disturbed regions break out again, mainly at high solar latitudes, in the opposite hemisphere, with opposite magnetic polarity. They increase rapidly in numbers until the next peak in the 11-year cycle of solar activity is reached. So the whole cycle is completed in about 22 years. The IGY coincided with the sunspot maximum of 1957–58, which was mainly in the Sun's northern hemisphere and had the highest activity on record.

As we see the Sun in the ultraviolet and X-radiations, which can be observed only by rockets far above our atmosphere, we see that the active regions are very limited in area. This activity largely coincides with calcium plages seen in visible light. There is some evidence that these active regions may always appear in about the same solar longitudes, so that one face of the Sun may be more active than the other. Thus, the Sun may have a kind of quasi-permanent geography.

A constant outpouring of particles moves from the Sun's surface into space. This is a solar wind across interplanetary space. It is the wind that blows the comets' tails always away from the Sun. These particles are intensely electrified near the Sun, forming the visible corona, which with the solar wind is stronger and more extensive near sunspot maximum. The solar winds are somewhat nonuniform in direction, and their movement produces a magnetic field and probably local electric fields. So, the whole solar wind is a plasma whose fields and particles permeate interplanetary space. About 40,000 miles above the Earth, the geomagnetic field equals the interplanetary magnetic intensity. Here the Earth's field must normally be bounded by the fields of space.

From time to time, in the vicinity of sunspot vortices, violent explosions occur that eject streams of intensely hot material of the Sun into space. These bright eruptions through the Sun's chromosphere produce brilliant spots that are intense sources of ultraviolet and X-ray radiations. These radiations strongly enhance the normal ionization of the Earth's atmosphere and cause coincident radio blackouts of long-distance radio in the sunlit hemisphere of the Earth. This increased ionization enhances normal electric currents in the high atmosphere, thus causing a corresponding cusp in the records of the magnetic field in the sunlit hemisphere. These explosions, or solar flares, also emit dense clouds of electronically charged particles, which carry with them a strong magnetic field. These clouds seem to be focused by the magnetic fields of space into remarkably well-defined tubes or streams. These streams move through space at about 1250 miles per second. Occasionally such a stream intercepts the Earth about a day after the eruption. Then it causes rather violent fluctuations in the strength and direction of the Earth's magnetic field, long known as a geomagnetic storm. More often, these streams miss the Earth altogether. But they can still be detected as they flow through space by their influence on cosmic rays, which are bent and focused as they pass through the streaming plasma. The direction of cosmic rays arriving at the Earth is noticeably asymmetrical when they traverse nearby streams.

With the interception of plasma streams by the Earth, geomagnetic storms seem to develop in three successive phases. As the intense, fast plasma interacts with the weak geomagnetic field some 40,000 to 25,000 miles out, strong electric currents are induced in the face of the stream. These currents cause a sharp change in the Earth's field, known as the "sudden commencement" of the magnetic storm. As the solar plasma piles up against the Earth's geomagnetic field, the normal field is seriously distorted, for the strong magnetic field of the plasma equals the Earth's magnetic field at a considerable distance inside its usual boundary. Thus, the plasma forces its way into the auroral zone in a ring about 20° to 25° from the geomagnetic pole. As the distortion spreads out around the polar regions, incoming particles produce auroras that appear farther and farther to the south, as the geomagnetic field is ever more distorted. The high atmosphere, 62 miles overhead in the auroras, is heated intensely by the impacts. Electric currents of millions of amperes are generated around the auroral zone and across the polar cap to form the polar phase of the magnetic storm. Finally, through the badly distorted and constantly fluctuating magnetic field, the particles are trapped in the outer Van Allen radiation belt. Just as in the Argus experiment, particles in this belt close around the Earth in a few hours when they form a ring of one or two million amperes around the equator. These currents fall off slowly in a few days as they produce the geomagnetic post perturbation.

Occasionally, very fine but very intense filaments of plasma, whose cross section is comparable in size to the Earth, are encountered before or during magnetic storms. They are not of sufficient extent to distort the field seriously. But the impact of these hydromagnetic plasmas compresses the geomagnetic field elastically. Then the field, and the ionized atmosphere it contains, oscillates reasonantly, producing micropulsations in the field and the atmosphere.

A few times near each sunspot maximum, a particularly violent solar eruption or explosion occurs, whose fireball of intensely hot material is projected a million miles or more above the Sun. These exceptional explosions propagate a true shock wave, whose tornado-like vortex below accelerates particles to a whole range of high energies. This synchrotron type of acceleration produces a characteristic type of radio noise, designated by scientists as Type IV, which heralds these extraordinary events. In exceptionally intense flares, the particle energies may reach billions of electron volts sufficient to penetrate the Earth's geomagnetic field and to be observed on the Earth as cosmic rays of solar origin immediately following the visible solar flare. But in all intense flares with Type IV noise, energies of hundreds of millions of electron volts are generated. Such energetic particles arrive at the Earth quickly, 1 to 4 hours after the flare, and long before the slower and less energetic but more intense plasma arrives to generate the subsequent geomagnetic storm. These million-electron-volt particles are not in sufficient numbers to distort the geomagnetic field or to penetrate it. But they are scattered downward into the polar cap, where the nearly vertical geomagnetic field does not inhibit them. Such scattered particles cause a prompt blackout of radio transmission over the polar cap 1 to 4 hours after the flare.

Now when such exceptional events occur, the subsequent magnetic storm about a day later is accompanied by what is known as a Forbush decrease in cosmic ray intensity that we now know to extend over an appreciable region of the planetary system.

Thus, out of the previous confusion of phenomena, a coherent picture of solar sources and consequent terrestrial reactions is emerging. Heretofore in the absence of sufficient knowledge, it has been unprofitable to speculate in any detail about how a stormy Sun controls our Earth's environment. Now we can begin thinking in detail about the consequences of solar changes upon our environment.

I do not imply that the interplanetary problem is solved, but only that we now have a tight grip on it: We need to explore and map out the interplanetary fields, both in the planetary plane and across it. We must measure the dimensions of the plasma streams and study their characteristics. We must find how they change with time. We can now ask a hundred sharp questions that are derived from reasonable hypotheses that our new knowledge permits us to formulate. About all, we must ascertain the effects of space phenomena on men who would be space travelers, and what measures are needed to protect them.

Events occur in such rapid succession that it is hard to remember that the launching of the Sputniks, the Explorers, the Vanguards, the Luniks, the Pioneers and the first men in space has all taken place in only 3½ years. While these preliminary exploration flights have produced scientific consequences of immense importance, they are but the forerunners of an unbelievable growth in scientific knowledge of our environment that is certain to occur in the next few years.

Consider the field of meteorology. The first TIROS satellite explored the cloud and storm systems of the Earth in a most preliminary way during the first 6 months of this year. TIROS I looked at a band around the equator some 50° latitude to the north and to the south. Its carefully designed optical system televised the Earth's surface and transmitted the resultant pictures back to the Earth through an intricate system of radio transmissions. These pictures are revolutionary in their impact on the science of meteorology. Storms can be seen readily, and the influence of a single storm system is now found to extend far beyond the limits that were previously supposed. The development of a hurricane system near Australia was watched in detail as the system grew and moved toward the coast. I might add that, without TIROS, the existence of that hurricane would not have been known. A strange and readily identified cloud system in an otherwise clear weather area was identified with the subsequent propagation of disastrous tornadoes. Pictures of the cloud cover of the Earth could be examined and compared with measurements made on another satellite, the Vanguard, which was mapping the heat balance of the Earth (i.e., the ratio of heat received to heat radiated at each location). Surprisingly, the heat balance at a given latitude was found to vary in the ratio of 2 to 1. Regions of negative or positive balance seem to move in which might be called highs and lows, with lows lying ahead of the polar fronts where high, cold clouds inhibit the radiation from the Earth. This mapping of the heat balance over the Earth must have most profound consequences in the future development of meteorology, since the map of heat balance represents the distribution of input and output energy in the giant heat engine that drives the Earth's atmosphere in generating the storm sources.

In another year, the more advanced NIMBUS satellite will map simultaneously the entire cloud cover and heat balance of the whole Earth, using much more advanced methods that have been learned from the pioneering knowledge of our first TIROS and Vanguard flights. An immense problem lying ahead is translating the detailed information thus acquired into a form in which the interactions of storms one on the other can be interpreted and predicted. Then, the information must be transmitted in sufficient detail and without delay to all of those whose vital activities depend upon the weather. No one can doubt that, with this vast new power to see the weather over the whole of the Earth, man's knowledge of meteorology will be expanded enormously and his ability to predict the weather and the climate will be increased noticeably.

Meteorology is but one aspect of the study of the Earth by means of instrumented Earth satellites. In geodesy, the study of the configuration of the Earth itself is already developing. We have found that the Earth is probably not the simple oblate spheroid that we had originally thought, but very slightly pear-shaped. As the shape of the Earth is defined, the information has immense bearing on its interior composition and distribution, so that space science will react on our knowledge of the interior of the Earth itself. More precise geodetic experiments to locate points on the Earth are now being readied. From these precise geodetic measurements, ideas of continental drift can be tested, so that our knowledge of the origin and movement of continents can be established without waiting a millenium.

The behavior of satellites shows clearly that the outer atmosphere is heated during the daylight hours and spreads many hundreds of miles outward in a huge bulge over the Sun. The whole question of how the Earth's atmosphere and its magnetic field couples into the plasmas of surrounding space remains to be explored in much more detail, but we are already satisfied that, in the outer reaches of the Earth's atmosphere were collisions between atoms occur infrequently, atmospheric atoms execute a variety of orbits right around the Earth, giving us a huge number of molecular satellites.

Looking outward, rockets and satellites are able to see the Sun and the stars in their full range of chromaticity from the longest to the shortest wavelengths. Man can now escape above his absorbing atmosphere, which has in the past restricted his view of the universe to a single octave of light. Thus, whole new opportunities in astronomy are just ahead as unmanned space observatories are launched. Preliminary space flights have already discovered spots of ultraviolet radiation coming from defined regions in space. The origins of this light are thought to be in clouds of excited hydrogen gas spotted around our galactic system. Likewise, the galactic system is being studied from space probes in the incredibly short spectrum of gamma radiation.

So the study of space astronomy is only beginning. Space platforms of great stability are now being constructed, and doubtless in another year or two the first great steerable space telescope will have been put into orbit. These space observatories will be controlled from the Earth and will permit man to search the heavens for new phenomena that will add enormously to our knowledge and comprehension of the physical processes of the universe.

Before going farther, let me comment briefly on the applications emerging from this scientific exploration of space. Immediately ahead we see a multiplication of long-distance communciations by a hundred times and at a fifth of the cost. The applications in meteorology of which I have spoken must be valued in the hundreds of millions. Space applications in the military field may well reduce the danger of war, with a consequent value beyond estimate. New forms of navigation will appear, and space science will produce new industry in a myriad of ways. So we must look at our space expenditures as investments to be repaid many times over in better products, services, employment, and convenience.

To many of us, the most exciting projects in space science lie in the now readily predictable capabilities to explore the planets. During the preliminary flights of the past two years, our payloads were restricted to a range of a few pounds to perhaps a ton or two. These were not sufficient to do very significant lunar or planetary exploration. Certainly, a useful result in this range of payloads has been the first crude mapping of the back side of the Moon by Lunik II.

But the next three years will see the payloads on spacecraft climbing into the range of 10 to 20 and perhaps even 50 tons. In this range of useful payloads, a whole new vista of planetary exploration is opened. The early experiments will fall into two categories. The first will be "fly boys" past the Moon or planets, followed by actual orbiting of these celestial bodies. In these experiments, photographs of the surface can be taken and measurements can be made in their atmospheres. Perhaps daughter rockets can be landed from the orbiting payloads onto the surface of the planet from which the preliminary messages of the character of the surface can be relayed back to us.

Likewise, soft landings of considerable payloads can be visualized. These unmanned landings can carry a variety of instruments of a quite sophisticated character. They can examine their planetary environment to give us the first descriptions of the real nature of the planets, their surface and atmosphere, and perhaps something of the character of life that may exist on them.

In outlining this program, one cannot underestimate the difficulties ahead. Perhaps the greatest of these difficulties lies not so much in the design of the vehicles themselves as in the radio and electronic systems that must control them and that must transmit back the information. The most serious problems of information theory and its applications to the experimental devices remain to be solved. Just how can one devise experiments to obtain critical and definitive results in a form so that the information can be automatically abstracted and coded and reduced to the extent necessary for its transmission back to Earth within a reasonable time? Over the immense planetary distance, our communication problem becomes extremely critical, for the amount of information that can be transmitted in a given time is critically dependent upon the weight and the power available to provide for such transmission. Reducing the information of an experiment to the essential minimum necessary to define the results clearly without redundancy will likewise take weight. The electronic and radio engineers must balance the competition between the weight required to acquire the data, to reduce it, and to transmit it, so that overall weight of the spacecraft is minimized. Ideally, one would like to reduce the data to be transmitted to a scientific paper, written by the machine on the planet. But I doubt whether our machines will reach this level of sophistication in the immediate future. On the other hand, our data cannot be so redundant as to require a hundred years for transmission with the power available to the planetary station.

In conclusion, I suppose I cannot escape commenting on the problem of man in space. In discussing this problem, I would clearly differentiate between man in orbit near the Earth; and man in space probe traveling away from the Earth into interplanetary space.

Already man in orbit and manned rocket travel have been achieved. This indeed may be a prelude to very high-speed space travel between points on the Earth. One might hope that an early step would include launching of man across the Atlantic to territories of friendly nations, or even, by prearrangement, to territories of the Soviet Union.

But man in true space is another thing. First of all, our preliminary experiments have shown that the radiations in space are intense, sometimes reaching the values of 50 roentgens per hour. You will recall that the lethal dose of radiation is about 400 roentgens, and at this rate, man in space has a very short life expectancy. But presumably in time after careful experiments, and with the use of shielding, man in space can be protected. Moreover, if he landed on the Moon or the planets, he should have access to materials from the surface from which adequate shields can be constructed. So with payloads on spacecraft of several hundred tons to carry food, water, oxygen, shielding, and the minimum comforts, man doubtless can eventually travel into space. But with the problems of science and engineering ahead, it seems very doubtful whether man can make his first useful trip from the Earth into true space before the 1970–80 era.

Therefore, man's first flights into space must be considered in the character of a training venture, since there is very little that man can do in empty space that instruments cannot do better. After all, instruments can be exposed to all of the elements that we wish to study in space, while man must be shielded from the very things we wish to observe. Therefore, one cannot imagine many useful duties that man could perform on a space flight. I assume, of course, a substantial measure of reliability in our instruments that we can confidently expect in the near future.

But man on the planets or the Moon is another thing. First of all, the response time for signals from the Earth to an interplanetary rocket is very long, from 5 to 15 minutes. In its approach to a planet, a 10- to 20-minute delay time in control response is a long time; therefore, it will be difficult to manipulate precise controls from the Earth. While instruments conceivably could do the job, man will probably be superior in controlling them.

Moreover, it is inconceivable that instruments can be designed that can fully appreciate the range of phenomena that can be explored. Here man with his superior brain as the computer can perhaps finally win the competition with the instruments and demand his right to perform useful functions in the exploration of space. But, with the competition of the electronic and radio scientists and engineers in this matter, I assure you that the competition between the capabilities of instruments and man is a rough one. For it will be a long time before man can be equipped to perform functions that several hundreds of tons of instruments cannot perform.

Yet I hope deeply that man will be able to travel to the Moon and the planets as soon as the necessary means have been devised, because of man's irrepressible curiosity and the courage of his spirit.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

PANEL DISCUSSION

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APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

1. ACTIVE AND PASSIVE LOW-ALTITUDE COMMUNICATION SATELLITES

by J. R. PIERCE*

"To everything there is a season, and a time to every purpose under heaven." Ecclesiastes 3:1.

At this particular time, I am going to talk about low-altitude satellites, that is, satellites a few thousand miles high, which rise and set in the sky, rather than satellites 22,300 miles high, which some day will hang stationary over one point on the equator. I believe that this is a very appropriate topic, because it is such satellites that we should be doing something about as soon as possible.

No one can doubt the urgent need for more transoceanic communication. Between 1959 and 1960, transoceanic telephone traffic increased about 20 percent; this corresponds to an increase of tenfold in about 12 years. Telephone service from the United States now extends to over 160 different political areas. Satisfactory agreements for cooperation with the communication system of each area have been worked out. There are now telephone cables to Great Britain and France, and to Hawaii, Alaska, Puerto Rico, and Cuba. Cables are being built from the United States to Bermuda, from Puerto Rico to Antigua, and from Florida to Jamaica. A third and broader band transatlantic cable, to Great Britain, is planned for 1963, and a cable between Hawaii and Japan for 1964. The total cost of all these cables is hundreds of millions of dollars. The cables to foreign countries are jointly owned by the American Telephone and Telegraph Company and the communication operating agencies of the foreign governments involved.

Such experience and projects show that neither political nor financial obstacles stand in the way of adequate international communication. The obstacles have been technical.

Satellite communication can and will overcome these technical obstacles and will provide adequate broadband circuits for transoceanic telephony within the means of the telephone systems of the world. The ultimate cost will be considerably less than providing such circuits by cable. Indeed, the American Telephone and Telegraph Company has announced its willingness to pay the cost of communication satellite experiments, including launching cost, and to bear its share of the cost of an operating system. When satellite circuits are established, they will be highly valuable for transoceanic television and data transmission as well as for telephony, and they will be valuable for many military purposes, just as transoceanic cables now are.

While satellite communication will overcome the technical obstacles that have prevented adequate transoceanic communication by other means, satellite communication itself has its challenging problems. Satellite communication will depend on the exploitation of two arts. One of these is a new, expensive, and uncertain art of space. We can judge this art in part by the facts that launching a small satellite today costs several million dollars, and that so far only half of our launchings have been successful. Of course, we expect cost per pound to go down and reliability to go up. Satellite communication can come into being only through this art, only through the use of vehicles that have already been developed at great cost by the Government primarily for other purposes.

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Even alterations of existing vehicles are technically very risky as well as costly.

The other art is the powerful, mature art of electronics. This has provided us with powerful transmitters, sensitive receivers, huge antennas, complex computers and tracking systems, and subtle methods of reception. The speed and success with which the Echo communication experiments were carried out is an excellent instance of our ability to deal adequately with electronic and mechanical problems on the ground.

Despite the fact that Echo's orbit changes rather rapidly, it has been possible to track the satellite to within 0.2° automatically by means of pointing directions computed from orbital observations.

Only about a hundredth of a millionth of a billionth of the 10,000 watts beamed at the Echo satellite is reflected into the receiving antenna. Nonetheless, by use of a maser receiver, which adds only as much noise as is equivalent to a temperature of 24 Centigrade or Celsius degrees about absolute zero, by using a horn-reflector antenna which does not pick up thermal radiation from the hot Earth, and by using broadband frequency modulation and a special narrow-band FM with feedback receiver, which tracks the modulation of the signal, it is possible to provide a high-quality telephone circuit. Telephoto and Speed-Mail signals have also been sent via Echo, and signals were sent across the ocean to Jodrell Bank, the Royal Radar Establishment, and the British Post Office in England, and to CNET in France.

While one could make a useful satellite system using Echo-type balloons, it appears that for many purposes active satellites containing microwave receivers and transmitters would provide cheaper and better communication.

In contrast with ground equipment, the problems of electronic and other equipment aboard satellites are difficult and uncertain. The space payload must draw upon new and old arts. Repeated operational failures show us that there is still much to be learned. And the dependability, the life of satellite electronic equipment, is of primary importance to satellite communication. The chief initial cost of a satellite communication system will be the cost of launching satellites. Unless the life of satellites is many years, the chief operating cost will be the cost of replacing satellites. The practicability of satellite communication depends on obtaining long life in the novel and hazardous environment of space.

Most active space payloads depend on solar cells, together with storage batteries, for electrical power. Sunlight has an energy of about 130 watts per square foot, and solar cells can turn about 10 percent or 13 watts of this into electric power, initially. It appears impossible to protect solar cells completely against the the effect of protons, which are very numerous in the inner Van Allen belt. While the discovery and exploration of the Van Allen belts is a major scientific feat, the extent, intensity, and composition of the radiation have not been carefully measured, nor their changes with time accurately determined. This makes our best present estimate of the life of solar cells uncertain by a factor of perhaps 12.

This is the time to make radiation measurements that meet engineering as well as scientific needs.

Undoubtedly, long life can be attained in space. The Vanguard transmitter is still functioning after three years in orbit. This is a remarkable achievement, but it must be remembered that this is a very simple, very low-power transistor oscillator, and enough solar cells were used to keep it going despite a drastic fall in their efficiency. More complicated satellite payloads have lasted as long as a year (an unsatisfactorily short life for a communication satellite), but many others have failed after a few weeks or a few months in orbit, and some have failed in whole or in part during launch. In general, we can say that it is possible though not easy to make simple, low-power electronic equipment operate reliably for many years without readjustment or repair.

Happily, if one uses maser receivers on the ground, fed by low-noise horn-reflector antennas, as was done in the Echo experiment, and if one uses a wideband form of modulation together with a suitable receiver, as was done in the Echo experiment, the transmitter power required in the satellite is small. In relaying 600 to 1,000 telephone signals or 1 television signal, 2 watts would be sufficient either for an unoriented or spin-oriented satellite with a nearly omnidirectional antenna at a height of around 3,000 miles, or for an oriented satellite at a height of 22,300 miles.

It is only through experiment that we gain sure knowledge. Through the Echo experiment we gained knowledge and assurance concerning receivers, modulation, tracking, and propagation. All of this is relevant to further satellite work. Now we need to show that we can achieve highly reliable, long-life operation of microwave equipment in space.

This is the time to launch a carefully designed, simple, low-altitude, low-power but realistic and broadband experimental satellite.

If a 22,300-mile-high satellite is ever to succeed, its attitude must be controlled so that a directional antenna can point to Earth. Attitude control would be desirable in low-altitude satellites if it did not unduly increase weight or decrease life.

Many attitude-control schemes have been proposed. I myself proposed in 1954 that the gravitational gradient be used. However, the orienting moment decreases as the cube of the orbital radius, and it is very hard to get adequate damping. The force of the Earth's magnetic field on a magnet suffers similar disabilities. How long will spinning wheels or gas jets actually function? If jets are used, will some momentary malfunction lead to permanent loss of orientation?

Today, no attitude-control system has actually operated at altitudes suitable for satellites, and no system at all has operated even for a small fraction of the time required for practical satellite communication. We can only conjecture what performance may be attainable.

Now is the time to actually build an attitude-control system that could be useful in a communication satellite and to test it thoroughly.

We can't test such an attitude control system in orbit, because no such system exists. When one does, then will be the time to test it in orbit.

If a 22,300-mile-high satellite is to hang stationary in the sky, the initial orbit must be corrected, and subsequent readjustments in orbit will be necessary. These can be carried out by means of gas jets or other impulse-producing means under radio control from the ground. Adequately reliable equipment for this purpose must be built and tested some time before we decide to use stationary satellites.

I have stated that this is the time to do certain things. I will now say what we should *not* do now.

We now need the knowledge and assurance that only further experiments can provide. But, if that knowledge is to be of any use to us, we must not act so as to preclude its use. We must not settle on one sort of satellite system to the perpetual exclusion of any other. If we do that, knowledge can no longer help us, and no just God would. I will go even further, and say, now is not the time to freeze the design of an (allegedly) operational satellite system.

The launching and experimental use of a low-altitude, spin-oriented, broadband, long-life satellite could add greatly to our knowledge and assurance with respect to both low-altitude and high-altitude satellites.

Concurrent radiation measurement experiments could put firm ground beneath our now dangling feet.

Experimental work on attitude control could enlarge the range of possibilities open to us.

All of this may lead to a 24-hour satellite as the ultimate and exclusive system. But when, if ever? Certainly, we could have reliable low-altitude satellites earlier. And, it is by no means clear that 24-hour satellites will be better for all purposes, even when we can have them. Let me list some of the advantages of low-altitude satellites.

(1) If I spoke to you via a 24-hour satellite, I could not hear a reply for over a half second. This would make a 24-hour satellite circuit somewhat inferior (we don't know just how much) to present transoceanic cable circuits.

This is the time to make extensive, realistic experiments on the seriousness of such a delay.

(2) Simple, low-altitude satellites will be lighter than 24-hour satellites, so more can be launched with a given vehicle. When one of a number of low-altitude satellites is not used for one path, it can be used for another. It may be cheaper to provide a given amount of world-

wide communication with low-altitude satellites than with 24-hour satellites.

(3) If one of a large number of low-altitude satellites in random orbits fails, the system performance falls off scarcely at all. If one of a few high-altitude satellites fails, the system performance is seriously impaired. A low-altitude satellite system would be less affected by accidental or deliberate destruction of satellites than a 24-hour satellite system would be.

(4) Finally, and of inestimable importance, it will be possible to make reliable, simple, low-altitude satellites before one can make reliable 24-hour satellites.

The launching of a simple but realistic experimental low-altitude satellite is the proper step toward a practical satellite system at an early date. This should be accompanied by concurrent work on the measurement of radiation and on attitude control and station keeping.

How fast we will really progress toward practical satellite communication will depend on what we actually do and learn. To every time there are appropriate and inappropriate actions.

This is no time to rule the future out of existence through baseless decisions, through monstrous paper systems plans, through a narrow and irrevocable commitment of the resources that are needed for the experimental evaluation of features and operation of various attractive communication satellites.

This is the time to undertake a simple, doable, promising experiment with a realistic, low-altitude satellite. That is what the Bell Laboratories are working on as hard as they can. They are working on attitude control and the effects of delay as well.

Insofar as we must plan beyond such experiment, let us not discard the things that we have learned we can do for things that we merely can't prove that we can't do.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

2. 24-HOUR COMMUNICATION SATELLITE SYSTEMS

by Elmer W. Engstrom*

We seem to be violating an old show business rule that says one should never follow an act by another act of the same kind. Dr. Pierce has just given us an excellent account of communication satellites. I also am going to talk about communication satellites. Luckily, however, there is plenty of room for all of us in outer space. I shall take advantage of that fact by moving out to a far greater altitude in covering my assigned subject.

We are all aware that increasing the altitude of a satellite increases the time it takes to complete each trip around the world. When we establish an orbit 22,300 miles up, the result is most interesting. At this height, in an orbit directly over and parallel to the equator, our satellite will take exactly 24 hours to complete one trip around the world. During the same time, the Earth itself will complete one full rotation on its own axis beneath the satellite. Thus, to a ground observer, the satellite will remain permanently fixed above one point on the Earth's surface.

The 24-hour, or synchronous, satellite is therefore of major interest to us for communication relay purposes. It offers the equivalent of the fanciful idea illustrated in figure 1, a fixed relay tower 22,300 miles high. The principle is, in fact, identical to that employed in the ordinary relay towers that dot the landscape around us, carrying television, microwave, and other communication services overland. With its immensely greater height, however, this imaginary tower in the form of a fixed active satellite will provide a single relay link that spans thousands of miles on the ground.

A RELAY TOWER 22,300 MILES HIGH

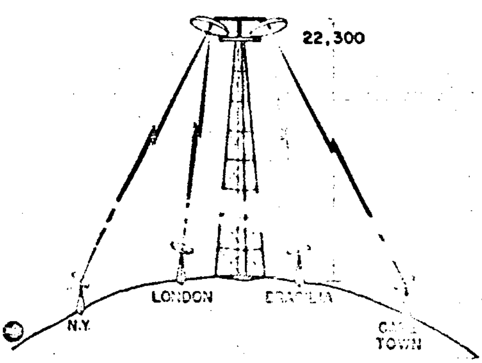


Figure 1

Several advantages inspire us in seeking to develop a stationary satellite relay system of this type. One is the prospect of world-wide service with satellites at only three locations. Another is the greater simplicity of the ground equipment for such a system in comparison with lower-altitude satellite systems. But by far the greatest advantage, and the one which constitutes our principal reason for working on this conception, is the kind of communication facility that can be provided *only* by a stationary satellite. With such a system we have the following capabilities that cannot be provided with a low-altitude system:

(1) Any number of ground stations can make simultaneous use of the single high-capacity repeater in the stationary satellite. This permits general access to the system for all users.

(2) Every ground station can communicate with any other ground station at any time. This means that every user can have his own ground station, located where it is most convenient to him.

*Senior Executive Vice President, Radio Corporation of America.

(3) Each ground station uses only that portion of the system capacity that it needs for its traffic at any given time.

(4) There is continuous, full intercommunication between all ground stations for technical and operational coordination of the system.

(5) The satellite repeater uses only two frequency bands—one for communication from ground to satellite, the other for communication from satellite to ground.

These features apply to all types of proposed service via relay satellites, including voice, teleprinter, facsimile, data, and television services.

The broad coverage that can be achieved with only two or three synchronous satellite relays is shown in figures 2, 3, and 4. In figure 2, we

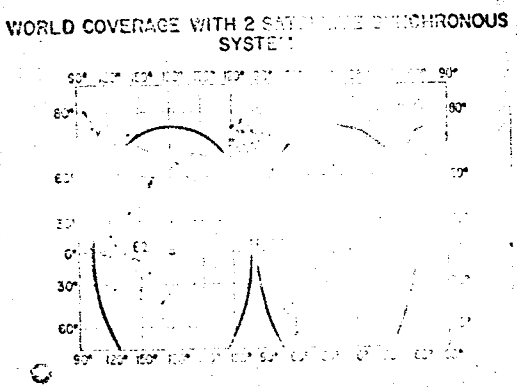


FIGURE 2

see the areas that could be served by just two satellites. One is positioned 22,300 miles above the South Atlantic, the other in a similar position over the Central Pacific. Together, they would provide links for virtually all major international communications areas. Through the Alantic relay, for example, permanent links would be provided between such scattered cities as Buenos Aires and Oslo, New York and Cape Town, or Miami and Moscow.

Figure 3 shows how the addition of just one more satellite would provide worldwide coverage with substantial overlapping. The service area embraces just about all of the inhabited land on Earth. In this arrangement, two of the satellites are placed in slightly different

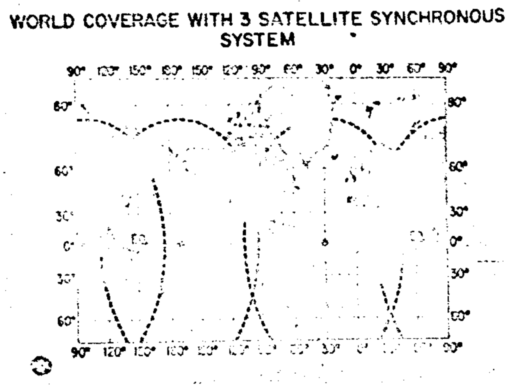


FIGURE 3

positions 22,300 miles over the equator in the Atlantic and Pacific, and a third is stationed over the Indian Ocean. An additional view (fig. 4) illustrates the three-satellite coverage

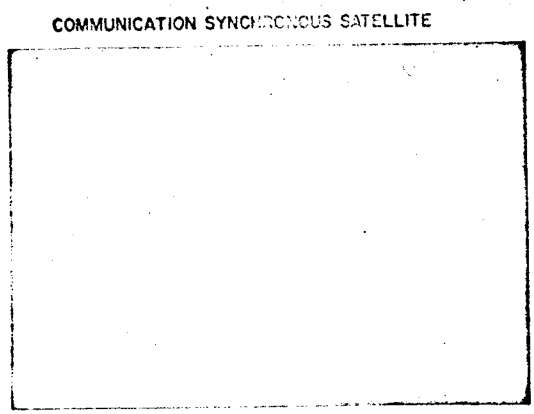


FIGURE 4

more graphically. This sketch shows us the arrangement as it appears from a point in space directly over either of the poles. You see how the spacing and altitude of the satellites over the equator provides coverage of the Earth's entire circumference.

As you heard from Dr. Pierce, the low-altitude satellite relay systems will require ground antennas that can track the multiple satellites one after another as they move from one horizon to the other. With a synchronous system of this type, there will be no need for tracking. Since the satellite remains in the same position relative to the ground, the ground-station antenna will be a permanent installation aimed always at the same spot. This means that the required ground equipment for the synchronous system will be substantially simpler and less costly. There will be no need for computing equipment to calculated orbits or for mechanical systems to move the antennas in order to follow satellites.

For the synchronous satellite we need, of course, to develop and refine the methods to position the satellite in a 24-hour orbit and to assure that it remains "fixed" in one spot relative to the ground. Also, we shall have to determine how best to keep the satellite itself in the proper attitude. Its antenna must always be pointed toward the Earth, and its solar-cell power supplies must always be kept exposed to maximum sunlight. The techniques for doing these things are known, but their successful application requires further engineering development.

Such work is now under way in the Army's Project Advent, which aims to place a synchronous satellite in orbit. We shall learn from this project much of what we must know in order to achieve a successful synchronous satellite communication system. We now have the electronic know-how for a reliable, large-capacity repeater system for a 24-hour satellite.

With a satellite 22,300 miles away, radio signals will take approximately $\frac{3}{10}$ of a second to travel from one ground station to another via the satellite. This delay is of no significance in teleprinter, facsimile, data, or television services. We do not know, however, what the reaction of telephone subscribers will be. In a telephone conversation the delay means that more than half a second will elapse after one party stops talking before the reply begins to reach him. Further testing is needed to study this effect, and this testing is under way in a number of laboratories. Some preliminary results have indicated that the delay is not of a practical limiting nature to satisfactory service.

Many of us feel that a major advantage of a synchronous system will be its direct accessibility for users in all countries through their

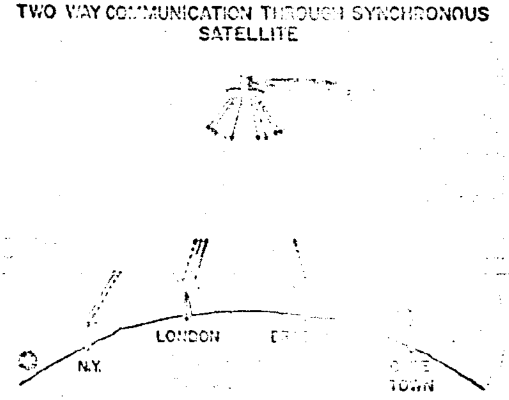


FIGURE 5

own ground stations. The concept is illustrated in figure 5. With the satellite permanently in view of major centers over a very large part of the Earth, permanent and direct channels of communication can be established through ground stations associated with these centers in the various countries. In this diagram, the colored lines represent channels allocated for voice, record, or television services. In accordance with the frequency allocation pattern established for the system, each station can maintain any required number and schedule of services with the others. This is an extremely simplified representation, since the capacity of the satellite in our present concept would be the equivalent of at least 1000 two-way voice channels or more, usable for telephone or record services, or a television transmission. It serves to demonstrate, however, that specific channels would be used for direct communication between any two points in the system.

The feature of direct accessibility, available only with the synchronous satellite system, is extremely important. It means that the various competing services in this country and the national services of other countries could use the satellite while continuing to conduct their business as they do today. None would have to depend upon a limited number of more elaborate ground facilties owned, operated, or controlled by others.

The satellite itself will be a relatively simple and highly reliable mechanism. One concept, which we have developed at RCA, is shown in

CONCEPTION OF A SYNCHRONOUS SATELLITE BROADCAST STATION

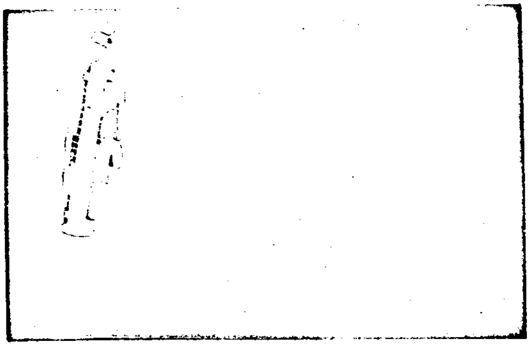


FIGURE 6

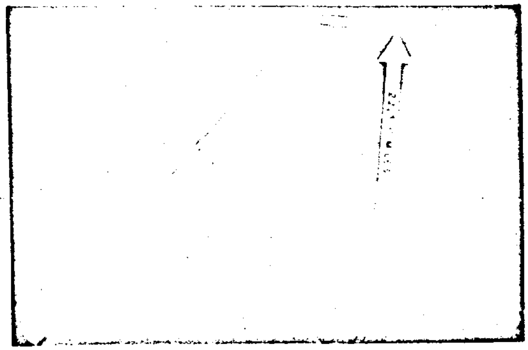


FIGURE 7

figure 6. The vehicle you see illustrated would contain equipment to receive, amplify, and retransmit the equivalent of 1000 or more two-way voice circuits for telephone and record service. The satellite would be 13 feet long and weigh about 750 pounds. Its electronic equipment would be powered by solar cells covering the two fins that extend from the cylindrical main body. Sensors, solar flaps, and servomotors would keep the satellite and its antenna in the correct attitude relative to the Earth and Sun. Small jet motors, remotely controlled from the ground, would be used when necessary to hold its orbital position against any tendency to drift.

To ensure uninterrupted service, we might place these satellites on station in pairs. Thus, the South Atlantic station you saw on the map might be occupied by two such vehicles spaced a short distance apart. Both could be used, and, if one should fail, the other would permit continuing service. Another satellite would then be sent up to restore the standby protection.

As we master the technology of synchronous satellites, we may look forward to systems that will provide other services. For example, we can envision a complete broadcast transmitter in space, providing radio and television programs directly to the homes of people around the world. This is in contrast to our contemplated relay systems, which retransmit only to ground stations for rebroadcast. An example of this concept is shown in figure 7, illustrating how a broadcast originating in, say, a studio in Liberia, could be broadcast directly to individual receivers over a large area of central Africa. The example indicates also the potential importance of such a system for wide areas in which there is an emerging need and desire for instruction and information. The equipment in the satellite would be the equivalent of the transmitter we use today to send a signal from a high building or tower to the homes of viewers or listeners over a wide area. This requires more powerful and heavier satellite equipment, of course, than does the communication relay function we have been discussing. Thus, the prospect of broadcasting directly from the satellite to individual home receivers is considerably farther away in time than is the relay system—but we should begin now to consider the possibility.

Satellites for broadcasting might not be of direct interest to commercial organizations for the type of programming with which we are familiar. However, the method should have real attraction as a means of education. This would especially true over areas where radio and television broadcasting is not now, and is unlikely soon to be, well established. Over large land masses, the problem of language differences would call for special care in scheduling both for geographic coverage and programming. Here, then, is a service the United States might consider pioneering for the benefit of all nations. The result could be a vastly powerful tool of education to be used in the cause of world peace and human progress.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

3. A REVIEW OF INDUSTRY PROPOSALS FOR SATELLITE COMMUNICATION SYSTEMS

by Herbert Trotter, Jr.*

The satellite systems that have been proposed by industry fall into three types:

(1) About 50 satellites in random polar orbits at a height of 2000 to 8000 miles, described by Dr. Pierce.

(2) Ten satellites in precision equatorial orbits at a height of 6000 miles with precision station keeping so they maintain equal spacing around the equator.

(3) The 24-hour or stationary orbit at 24,300 miles as described by Dr. Engstrom.

In their proposals to the Federal Communications Commission, the companies answering the inquiries had a variety of methods for the technical operation and business management of a worldwide satellite system:

(1) A. T. & T. proposed that their random polar-orbit system be jointly owned by the U.S. international communication common carriers and their counterparts abroad. The U.S. ownership would be divided according to the estimated use by each of the participating carriers.

(2) The General Electric Co. proposed that the ten station-keeping equatorial satellite system be a joint venture owned by interested companies with no company owning over 10 or less than 5 percent. Their system would allow five ground stations to talk to each other through one satellite. The twelve channels through each satellite allow four 252-voice channels and eight 24-voice channels.

(3) General Telephone & Electronics proposed a highly flexible worldwide communication system having the characteristics that

(a) Each ground station is capable of communicating with every other ground station.

(b) Each two-way communication channel through the satellite can be used by any pair of Earth terminals.

(c) Channels are allocated to customer common-carrier companies only as the demand for service requires.

They proposed the formation of a commercial satellite communications company to be owned by all existing and future domestic and international U.S. communications common carriers that elect to participate with availability for use by all, regardless of ownership.

(4) Hawaiian Telephone Co. wants to participate financially in the system that will serve the Hawaiian Islands.

(5) International Telephone & Telegraph proposed that ownership of the system be in proportion to use but with right to lease facilities if ownership is not desired.

(6) Lockheed proposed a satellite system identical to General Telephone & Electronics. It proposed "Telesat," a "common carrier" concept with ownership by three groups:

(a) U.S. Common carriers.

(b) Other private industrial and commercial companies.

(c) The general public.

(7) Press Wireless proposed that each U.S. international communication carrier should be allowed to use satellite either by lease or purchase.

(8) R.C.A. proposed the stationary satellite system with each U.S. carrier and each overseas administration owning its own ground stations and allowed to operate through the satellite.

(9) Western Union Telegraph Co. proposed a joint common carrier owned by private industries and providing service to each common carrier through their ground connection to the satellite base.

*President, General Telephone and Electronics Laboratories, Inc.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

4. THE ROLE OF THE FEDERAL COMMUNICATIONS COMMISSION IN COMMUNICATION SATELLITES

by T. A. M. CRAVEN*

The world presently is standing on the threshold of one of the most significant achievements that mankind has yet conceived in the field of long-distance communication; namely, worldwide radio communication through the use of satellite relays.

Through the combined efforts of industry and government, the United States, already possessed of the most efficient and progressive communications system in the world, stands poised to throw the combined ingenuity and resources of industry and Government into the establishment of an international satellite radio communication system that would provide direct communication between this and all other countries and, at the same time, be susceptible of use by all other nations for communicating among themselves.

The Federal Communications Commission has delegated to me the task of spearheading the industry-FCC endeavor to institute such a worldwide satellite relay system at the earliest date possible, and you can be assured that my efforts, as well as those of my personal staff and other Commission employees who constitute the FCC Space Team, are directed toward the licensing of a private organization which, it is hoped, will be ready soon to go forward with the research and development phase of the proposed radio communication system.

Many, if not all of you, are aware that the Commission is not the only arm of the Government involved in the establishment of this new system of international radio communication. The Departments of State, Defense, and Justice, as well as the National Aeronautics and Space Administration, and The Office of Civil and Defense Mobilization also are playing a large part in the establishment and operation of such a system. However, time does not permit me to go into various questions which concern these branches of the Government, except insofar as I may touch upon them tangentially as I discuss the Commission's role in the establishment of an international radio communication system using satellite relays.

The Federal Communications Commission is responsible for the administration of the Communications Act of 1934, as amended, the primary purpose of which is to make available, as far as possible, to all the people of the United States, a rapid, efficient, nationwide and worldwide wire and radio communication service, with adequate facilities at reasonable charges. To this end, the Act directs the Commission to keep itself informed as to technical developments and improvements in wire and radio communication so that the benefits therefrom may be made available to the people of the United States, and to study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest. Further, the Communications Act gives to the Commission exclusive jurisdiction to authorize all nongovernment radio operations in interstate and foreign commerce through the issuance of construction permits, station licenses, and certificates of public convenience and necessity, upon finding that such operations are in the public interest.

The Commission, in accordance with its statutory responsibilities, has kept pace with, and

*Commissioner, Federal Communications Commission.

acted in response to, the rapid developments in the new technology of space satellite relays for radio communication between points on Earth. It believes that the earliest possible realization of technically and commercially feasible space communication systems for use by the public will not only demonstrate the advantages such systems offer to us and the other nations of the world over conventional means of communication, but will also demonstrate to the world our leadership in the application of space science to peaceful and practicable ends.

These systems, which the Commission believes will be of most value initially in intercontinental communications, will relieve the present congestion in the radio spectrum. The much-needed additional capacity they promise to afford will be available to accommodate the rapidly increasing growth of commercial common-carrier communications. Their technical characteristics will also permit institution of new services, such as wide-band data transmission and intercontinental television relay.

The Commission has been devoting considerable effort to a resolution of the problems involved in the realization of commercially operable satellite communication systems. Our activities in this field reflect our conviction that such systems will and should take their place within the framework of our free-enterprise system, under which public communication facilities are owned and operated by private companies subject to government regulation. The merits of such a policy have been amply demonstrated by the record of achievements attained by our communications industry in providing a high quality of service at reasonable charges to the public.

The launching of the communication satellites into orbit will, of course, require the cooperation of the National Aeronautics and Space Administration, otherwise known as NASA, which also has a significant role in the research and development work on communication satellites. The Commission and NASA, cognizant of the need for mutual cooperation, have jointly signed a memorandum of understanding, setting forth certain conditions of fact and policy guidelines. Each has agreed that the earliest practicable realization of a commercially operable communication satellite system is a national objective, and each has agreed to conduct its respective activities with a full exchange of information so as to accelerate necessary research and development and to coordinate governmental actions necessary to attain the national objective.

As I have indicated, the Commission is also working with other bodies, governmental and nongovernmental, which are concerned with the new space technology. Thus, for example, it has participated in the work of an *ad hoc* committee, of which I was Chairman, in drafting policy recommendations on space communication systems for the Telecommunications Coordinating Committee (TCC) of the Department of State.

The Commission is also participating in the work of the International Radio Consultative Committee (CCIR), with other United States representatives in studying the international aspects of the technical side of space radio requirements. These studies will result in recommendation to the CCIR's plenary meeting at New Delhi in January 1963. The work of the United States representatives, under the sponsorship of the Department of State, is proceeding on a broad front and is scheduled to be completed well in advance of the scheduled meeting in order to provide adequate time for circulation of our views abroad.

There are, of course, problems presented by the new space science that must be resolved before a commercial space satellite communication system can become a reality. The Commission is doing all that it can to aid in a resolution of these problems as rapidly as possible. In this connection, certain of our actions and activities appear worthy of mention.

In early 1957, the Commission recognized the need for international agreement on the allocation of spectrum space for space satellite communication and other related space communication functions. Accordingly, it undertook, in conjunction with the Department of State and other government agencies and interested segments of the communications industry, extensive studies that ultimately led to the formulation of space communication proposals, which were presented at the 1959 International Administrative Radio Conference in Geneva.

A feeling, not shared by the United States, generally prevailed at the conference that too little was known at that time about the actual needs of an operable space communication system to warrant the allocation of wide bands of spectrum space for operational space communication purposes. Nevertheless, inspired as it was by the initiative and urging of the United States, the conference did make available, on a shared basis, certain frequency bands for space research. In addition, the conference recognized the necessity for the International Telecommunication Union (ITU) to provide adequate frequency allocations for all categories of space radio communications at the earliest practicable date. Accordingly, it adopted a resolution that provides for the convening of an Extraordinary Administrative Radio Conference tentatively scheduled for the latter part of 1963 to consider the allocation of frequency bands required to support both research and operational phases of the various categories of space radio communication. Since the adjournment of the 1959 Geneva Radio Conference, the Commission has been actively engaged in preparatory work for the 1963 Extraordinary Conference.

In this regard, the Commission, in May 1960, instituted a formal inquiry looking toward the formulation of proposals to be made by the United States at the conference. The issues in this proceeding include the feasibility of sharing Earth-space-Earth and space-space frequencies with existing fixed and mobile operations, the amount of spectrum space required for the various space communication functions, the most desirable portion of the spectrum within which such functions can be accommodated, and the degree of protection from harmful interference required by each such function. Responses have been filed by a large number of interested parties and are currently being evaluated.

Thus far, most of the Commission's recent work on proposals for radio-frequency allocations to support the space program has been done in consultation with the Office of Civil and Defense Mobilization (conveniently referred to as OCDM) and the Interdepartment Radio Advisory Committee (otherwise known as IRAC) on a security classified basis. It is expected that very shortly we shall be in a position to publish, for industry comment, a comprehensive first proposal on the kind of frequency support for which international agreement appears to be necessary, if the full benefits of space technology are to be made available to all the peoples of the world. Specifically, the proposals deal with allocations for space research, weather satellites, and communication on a satellite relay basis. Thereafter, we anticipate that parallel recommendations will be made to the Department of State by this Commission and the OCDM, for the purpose of circulating our views abroad. The objective is to secure the widest possible area of agreement among the Administrations that are members of the International Telecommunication Union well in advance of the convening of an international conference on frequency allocations for space.

In addition to work being done on frequencies, the Federal Communications Commission is encouraging experimentation by private industry to develop constructive technical information in furtherance of the country's overall space program. In recent months the Commission has granted experimental licenses to the Collins Radio Company, the Federal Telecommunications Laboratories Division of International Telephone and Telegraph Corporation, and Westinghouse Broadcasting Co., Inc., authorizing the bouncing of signals off the Moon and/or manmade passive satellites for basic research and study. The American Telephone and Telegraph Company has been granted an authorization to conduct an experimental program with active satellites. Pending in the Commission at this time are several applications for authorizations in the research and development phase of the proposed satellite radio communication system, and early this month a subsidiary corporation of General Electric Company applied for a license that contemplates the establishment of an operational service as distinguished from an experimental one.

In addition to the technical considerations that relate to space communications in general, there are legal, administrative, and regulatory problems relating specifically to the authorization of commercially operable communication systems on which the Commission is working in cooperation with the industry and other government agencies.

The Commission's most immediate and vital concern in this area arises from the likelihood that it may not be feasible to have more than one or a limited number of commercial satellite communication systems, because of the substantial capital investment required and limitation of spectrum space available to accommodate several systems. This raises a problem as to the manner in which such a system or limited number of systems can be accommodated within the Commission's policy of fostering beneficial competition in the international communication field and within the antitrust laws. The Commission, believing that prompt consideration of this problem would avoid delays in the establishment of commercial communications via satellites, instituted a formal inquiry soliciting views as to the best method of insuring that international communications common carriers, and others, participate on an equitable and nondiscriminatory basis in a single or limited number of satellite communication systems. Views were also solicited as to the legality of the suggested method; the Commission's power to require such method; the extent to which participants in the plan would be subject to the Commission's jurisdiction; and whether respondent intended to participate in such plan.

It is the Commission's expectation that a resolution of the questions involved in this proceeding will establish criteria governing, in this respect, the future authorization of space communication systems for commercial use. The establishment of such criteria in advance of the issuance of authorization will aid private entities interested in the development and operation of such systems. Knowledge of the Commission's requirements as to participation in such systems should encourage them to proceed with the formation of appropriate organizations or arrangements. This should, in turn, encourage further use of private capital in the development of space communication systems.

Since the administration of the antitrust laws by the Department of Justice is involved, the Commission believes that coordination with the Department will facilitate consideration of this matter. It has, therefore, established liaison with that Department, which has indicated its willingness to cooperate, so that views may be informally exchanged on the matter, where proper.

Responses to the inquiry and reply comments already have been filed. Analysis thereof is under way and it is expected that the Commission, after filings are complete, will shortly take further steps in this matter.

Precisely what these steps will be I am not in a position to say, but it is the Commission's aim to discharge its responsibility in this regard at the earliest possible date, and I assure you, as the Commission's spokesman with respect to this matter, that I will do everything in my power to make certain that there will be no unnecessary delays on the part of my agency in the licensing of a satellite radio communication system.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

5. IMPLICATIONS OF COMMUNICATIONS SATELLITES TO THE U.S. INFORMATION AGENCY

by Edward R. Murrow*

I have looked forward with keen anticipation to this meeting—not for what I would say but for what I would learn. I have listened with interest to my fellow panelists, and the enlightenment of their remarks only reinforces a conclusion I just stated: namely, that I am out of my league. Your participants these two days have been drawn from impressive scientific backgrounds, top administrators from preeminent institutions, all with their eyes trained on the heavens. I bring credentials primarily as a reporter; my background in science is confined to the one technical conclusion that I was able to wring from 25 years of broadcasting: namely, the long waves are in fact short and the short waves are long.

I have traded my microphone for a meeting table. The change has been invigorating. But I might question your premise that because I now reside on the new frontier of politics I am therefore qualified to speak on the next frontier of space. I read your purpose in this conference as being "to bring together an array of some of the best minds in space and related fields." I feel myself at best a distant, though I hope respectful, relation. In your array of dazzling minds in space I feel my own lustre appropriately dimmed by the company in which I stand.

At the risk of being the one rocket on your panel that fails on the pad, I'm going to assume the role of the Socratic interlocutor. I do this in no sense to doubt the necessity of the program but rather to propose certain questions for discussion by experts.

*Director, United States Information Agency.

The most incisive letter I ever received in a quarter century of newscasting was a missile-like missive from a lady who had long listened to me but wrote: "Not only do you not tell me anything important but you don't even ask me interesting questions." I hope at least to ask some interesting questions.

I would speak to you today not as the head of a technical agency but as a person identified with the problems of policy and the feelings of people. I share with you an excitement about the future. Communications systems in space can help unburden communications systems on Earth. Subways and highways will continue jammed, but at least while waiting for commuter routes to unclog we may someday be able to watch live the latest TV from Europe. Broadcasting, of course, is the main reason our Agency is watching developments in space. Whether done directly or by point-to-point relay, we have a large and obvious stake in any improvement in bombarding the world with words and music and pictures.

And that is precisely the point. We can orbit our rockets and transmit our broadcasts, but in the end we still deal with the basic elements of human communication: words and pictures. Space satellites will not make it any better; it will simply diffuse it over a wider area.

On a basis of policy, politics, and content, space communications will not solve the fundamental problem of communications, one that has haunted man since time immemorial: What is he to say and how is he to say it? A communication system—even one in space—is totally neutral. Batteries and wavelengths have no vocabulary. A transmitter whether on the Earth or in the atmosphere does not know what to say. Communication systems have no conscience, only a history. They will transmit both filth and inspiration with equal facility. The mistakes—and they will abound as much tomorrow as they do today—will still be made by humans.

With apologies to my fellow panelist from the F.C.C., Mr. Craven, I suggest that here is where the "wasteland of television" speech by Mr. Newton Minow imposes itself on our thoughts. Even beyond that wasteland, do we really want the world, without the context of background knowledge, to see TV covering the bloodlettings and bus burnings in Alabama?

Space satellites will neither solve our dilemmas nor salve our conscience. Television and radio are still television and radio, whether sent from a tower 500 yards away or a satellite 500 miles above.

But even beyond our sins of society there are grave matters of international policy. Any system, I take it, by its nature must be global. One does not send a signal to a satellite and have it die there. There must be a terminal point in another country. Like Pandora glimpsing inside her box, the problems begin to appear. We must in some cases at least use facilities of other countries. How? Shall we do it by agreement with them? Broadcasting needs frequencies. In developed countries these frequencies have been distributed.

There may be a major problem of finance; who pays for the system? Participation by many smaller nations may involve an outflow of hard currency when they can ill afford the loss of international exchange. The problem then becomes a mixture of the engineering, the legal, the political, the financial.

There is another international barrier that is at least worth mentioning: the difference in international broadcast standards. Television in the United States is different from Television in England, Russia, and France. Standardization has great merit, but a nation's individual standard is precious to it. Besides the bald element of national pride, control of standards mean, as I understand it within certain limits, control of what people see and hear. This would bring us in conflict not only with other countries but even with ourselves. What American engineer, for example, would recommend overhauling U.S. television production standards to gain international compatibility?

In the field of space satellites, international amity must be based on domestic unity. And domestic unity about space communications seems to be somewhere on the horizon. There are at least three major policy areas upon which agreement must be reached.

One, shall the space system be Government or private enterprise? The problem has been ingrained in our past and is probably ordained for our future. Even if a decision were made for private enterprise, the capital requirements are so enormous that there would have to be some Government participation.

Two, shall the system be military or civilian? Both have good arguments. Space communications can have endless military purposes; what national leader would deny its use for defense of our democracy? But I mentioned earlier that we must have the cooperation of other countries. If the system is military, will this make it unattractive in convincing other countries to participate?

But we don't solve these problems by opting for a civilian system. There are still Government needs for security and national defense. Further, should only one communication carrier run the system and lease facilities to other carriers? Or perhaps to be fair we should let the companies merge to form one surviving carrier for international communications.

Three, underwriting the cost. Will we make the system pay its own way abroad, subsidize it in part, or give it away free? Although foreign cooperation is important, many countries cannot afford the cost of a satellite participation.

Communicating around the world is expensive. To the extent communication costs are high, the free flow of information is hindered. If costs for a satellite system are higher, which now seems reasonable, the flow of information will be hampered even more.

All of which brings me to the uncomfortable subject of paying the bill. Experts agree on only one thing: The astronomics of space become the astronomics of money. Beyond that, estimates diverge like forks in the road.

It is here that I make certain emphasis for our Information Agency. A system of communications satellites will be meaningful for our Agency only if it is a cheap system. We cannot squander millions for the novelty of using a new satellite system. On our Agency budget we must staff and maintain over 200 posts in nearly 100 countries around the world and carry on a range of highly diversified activities. Broadcasting is only one of those activities.

Satellite communication will be an additional system of communications. Not a completely new system, but an additional one.

We will still broadcast standard-band radio; there will still be normal broadcasting of television. The satellite system will be an expansion and expensive, but it is unlikely to be a replacement.

There is a further problem in the power system to be used. How does one send the best signal to a satellite and then back to Earth? We must be competitive in our broadcasting. People will not listen to or watch a signal if that signal is weak or distorted. They will turn to the signal offering the best quality of reception. There must be good transmission, consistently every day of the week, every week of the year.

There may be another issue worth discussing. Let us call it the "gimmick value" of the satellite. When a person can receive our radio on normal broadcast bands, and TV over normal broadcast channels, why should they ever bother looking or listening for the same programs merely because we have beamed them via satellite? For the first few weeks it may have the gimmick value of inducing an audience. But when the honeymoon is over and our marriage between programming and audience has settled into its day-to-day monotony, satellite broadcasting may offer little more in any areas than we offer today.

We have flown Commander Shepard's Mercury capsule to the United States exhibit at the 24th International Air Show at le Bourget in Paris. There over a million people at the world's largest international exposition on aviation and space will see this symbol of the latest American space success—and this on the very site where nearly a generation ago a slim lad named Lindbergh landed his "Spirit of St. Louis" after another historic flight over the Atlantic.

One assessment we will have to make is how we choose to shape our lives and our fortunes. This generation of Americans has no monopoly on problems. They abound abroad. Over much of this globe there are unfed bellies and tired bodies that will turn to our satellite system with but marginal interest. The grindstone of poverty will still be the lodestone of policy. It would seem the level of living would be a relatively high priority for this generation to face. Maybe schools and sewers in certain developing areas are more important than satellites.

I have come today not to doubt your hopes. If we would do this job, there is much to consider. There is hard work as well as harsh risk. I once knew a man, who in the twilight of his colorful career would flee into the house when an airplane passed overhead; when asked why, he would respond: "Someday one of those things'll drop a monkey wrench."

I suppose that there may be monkey wrenches dropped in this vision.

I pick no quarrel with a dream. And the hope of a world system of communications with satellites may be a dream worth the trying. But history will record that there were more people than there were nations, and more dreams than there were people. Not all of those dreams could be delivered to reality. It may be that the history of our day will be decided by what dreams we choose to deliver. The issue, gentlemen, is not how we deliver it, but what our delivery has to say.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

6. INTERNATIONAL IMPLICATIONS OF GLOBAL COMMUNICATIONS VIA SATELLITES

by Philip J. Farley*

Communications satellites as they regularly circle the globe will be inherently international. They will provide a new technological means of overcoming the long distances across the oceans and of communicating between continents and among nations. They can encourage the geographic pattern of communication to become truly global. They should facilitate direct communication between countries and alleviate to a considerable degree the present requirement to pass through third countries. The impact of communications satellites will thus be international, and the public they serve will be an international one.

There are a number of ways in which an operational communications satellite system could be designed to make it most responsive to the interests of the world community. It is the spirit of the U.S. space program that nothing less than the optimum objectives will satisfy us. In this spirit, the most useful features we can envisage, and nothing less, ought to be the criteria for what is acceptable in space communications.

Let us look at some of the criteria of an internationally useful satellite system.

A first criterion is opportunity for other countries to have access to the system. The system should be designed with a view to offering as soon as possible service to the broadest area of the world. It should not cover merely the areas of heaviest traffic. Nations wishing to make use of the satellite system not only should have ready access to it, but also should be afforded a share in its ownership and a voice in its operation if they wish. A truly global system must be one in which many nations feel they have a stake.

In designing the system, special weight should be given to design characteristics that will facilitate global coverage and use by countries with a small volume of traffic. The minimum price of admission to the system should not be an elaborate ground facility far exceeding the prospective volume of traffic. This consideration will have special interest to the small and developing countries, since they are faced with the problem of balancing their arrangement for external communication simultaneously with the growth of internal communications capabilities. They can be expected to have an interest in the system, however, since it will offer them a new and ready means of establishing links with the outside world. Clearly we should from the outset avoid thinking of this as a United States-oriented system; we should think of it as a system that could potentially meet the needs of all countries whether to communicate with us or to communicate with each other.

A criterion that has political as well as technical force is the need for maximum economy and efficiency in the use of the frequency spectrum. The prospect of relieving the mounting pressures on the frequency spectrum, in handling a greatly increased volume of traffic of various kinds, is one of the generally recognized potential benefits of satellite communications. However, different approaches to communication satellite systems vary in the degree to which they consume or conserve frequencies. We should favor designs that conserve rather than abuse the frequency spectrum.

*Special Assistant to the Secretary of State.

We in the State Department, and particularly my colleagues in the Telecommunications Division, have a special interest and responsibility in this regard. The Department is looking forward to an Extraordinary Administrative Radio Conference to be held under the auspices of the International Telecommunications Union (ITU), possibly in 1963, for the purpose of allocating frequency bands for space activities. Allocation of adequate radiofrequencies for communications and other space activities is dependent on a favorable outcome of this conference. Our chances of such a favorable outcome will be greatly enhanced if the space communications plans which the United States is taking the lead in developing are reasonable both in their anticipated use of frequencies and in the benefits such use will bring to the other countries who will join in the allocation decision.

A related consideration is the design of a system that will avoid interference between users of satellite relays, between space and ground communications, and between space-relayed messages and other command and tracking communications between the Earth and satellites.

A quite different need is a prompt decision to proceed to establish an operating satellite communications system. In addition to the basic desirability of getting ahead with this useful program under U.S. leadership, there is the international consideration that other countries should have a reasonably firm planning basis in forecasting their long-term communications needs and ways of satisfying them, so that they can work effectively with us in plans for satellite communications.

A related and to some degree offsetting criterion is the importance of designing the initial operational system in a way that will facilitate expanded future satellite communications operations. It is desirable to fix on design of an operating system promptly, but early availability should be matched with maximum usefulness, both in the short term and as one looks ahead to ultimate requirements for space communications.

Another criterion of an operational system should be its availability for international public-service applications. The kind of thing I have in mind is emergency international peacekeeping or relief activities by the United Nations or other responsible organizations. As another example, there may well be special requirements for communications services for such functions as the collection and dissemination of meteorological data (including the great new body of weather data that may be made available from meteorogical satellites). Should effective arms-control agreements be reached, the inspection operations that would be carried on would have special requirements for rapid and reliable communications, often from spots not readily accessible to existing communications nets.

I would like, in conclusion, to call attention to the genuinely liberating and constructive effect this technical achievement can have on human affairs. Often we are more conscious of the obstinacy or even malignancy of the gadgets men have built and become dependent on. I am told that this contrariness is particularly recognized in space launchings, where it has been formulated as Murphy's Law: If anything *can* go wrong, then it *will*. The law is of course equally familiar to all householders who have tried to start a balky power mower. But actually, it is the conditions of life on this planet that are indifferent or hostile to us, and technology makes it possible to master these conditions: Technology is in effect beneficent. Without it, we could neither support the burgeoning human race nor organize human interrelations so that it remains possible for us to live together.

In organizing human interrelations, communications are of crucial importance. And recently, we have been facing a gradual constriction in meeting communications needs, because of the natural limitation of the frequency spectrum. This constriction could be serious not only for commerce but also for efforts, national and international, to create the political order in which new individuals and new states can live together peaceably and productively. In political organisms as in animal organisms, development of higher forms requires development of flexibility and responsiveness of the nervous system. In the political organism, communications are indispensable to the perfection and refinement of the unifying nervous system. Unless the volume, versatility, and precision of messages and the variety and directness of interconnections between parts of the body politic can continue to grow in number and complexity, development will be halted. Here is the real international significance of communications satellites. If properly used, they will overcome the natural obstacles that distances and the restricted frequency spectrum place in the way of continued growth and refinement of the world's nervous system. Properly used, they can ease and even facilitate the task of resolving international differences and attempting to move one stage further toward an orderly and peaceful world.

The United States takes pride in its scientific and technological pioneering. We have shown a rare bent for making the fruits of science and technology available to our own people and those in other countries. But the kind of pioneering that is most characteristic of us and still most needed is the leadership in devising and strengthening political institutions to preserve freedom and unite the efforts of nations to resolve their differences peacefully and to build an orderly and prosperous world community. We shall need every tool we can find for these purposes—and not least of these, the new space vehicles. Surely we will not be satisfied unless the communications satellite system we shall soon be establishing responds fully to these political opportunities.

cyclone family extending from central Canada westward to south of the Aleutian Islands. Note the spiral cloud formations of these individual storms, particularly the most intense one at the left, the long narrow frontal cloud system and its accompanying upper jet stream of winds connecting it to its dying storm-partner in the Gulf of Alaska, the thin, curved cloud "streets" composed of small convective clouds such as showers and thunderstorms forming in the cold air streaming from Alaska over the warmer ocean, and the widespread fog and stratus docks south of the westernmost storm caused by warmer air moving northward over colder water. A meteorologist having only this cloud information in the form of "Nature's Weather Map" could acquire a rather good qualitative picture of the main weather features over this tremendous area. When this information is regularly available and combined with conventional data such as winds, pressures, temperatures, and so forth, available at only a few spots in the North Pacific Ocean, the resulting weather map will be far more complete and detailed than now. This is important, since most of the weather systems affecting Canada and the United States move in from the North Pacific Ocean.

In figure 2 there is shown a large individual storm centered over Nebraska, and affecting the Mississippi Valley, which was observed by TIROS I on April 1, 1960, the day it was launched. This large storm has an extensive cloud area around its center and a long frontal cloud extending to the Gulf of Mexico, where it joins a rather extensive cloud mass. Thunderstorms are imbedded in this frontal cloud from St. Louis, Missouri, to the Gulf of Mexico.

In figure 3, a hurricane located 300 miles north of New Zealand on April 10, 1960, is shown with its characteristic spiral formation so well known from radar photographs of hurricanes. I show this because Oklahoma often is afflicted by the backlash of hurricanes moving inland from the Gulf of Mexico; weather satellites should help detect and track these dangerous storms.

This is demonstrated in figure 4, which shows a hypothetical evolution of a hurricane

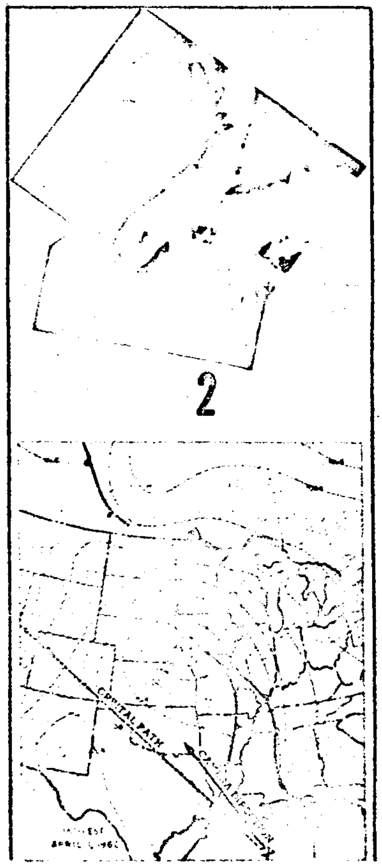


FIGURE 2

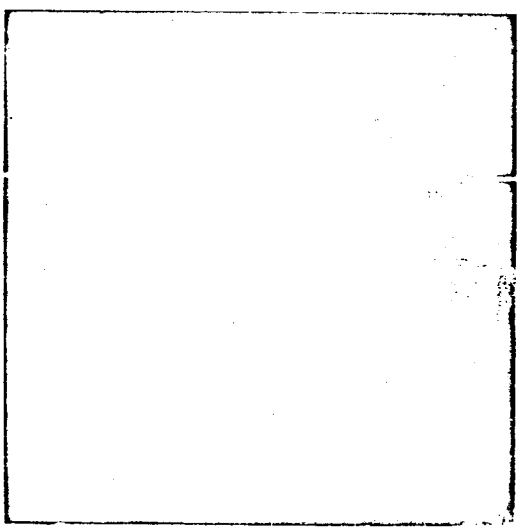


FIGURE 3

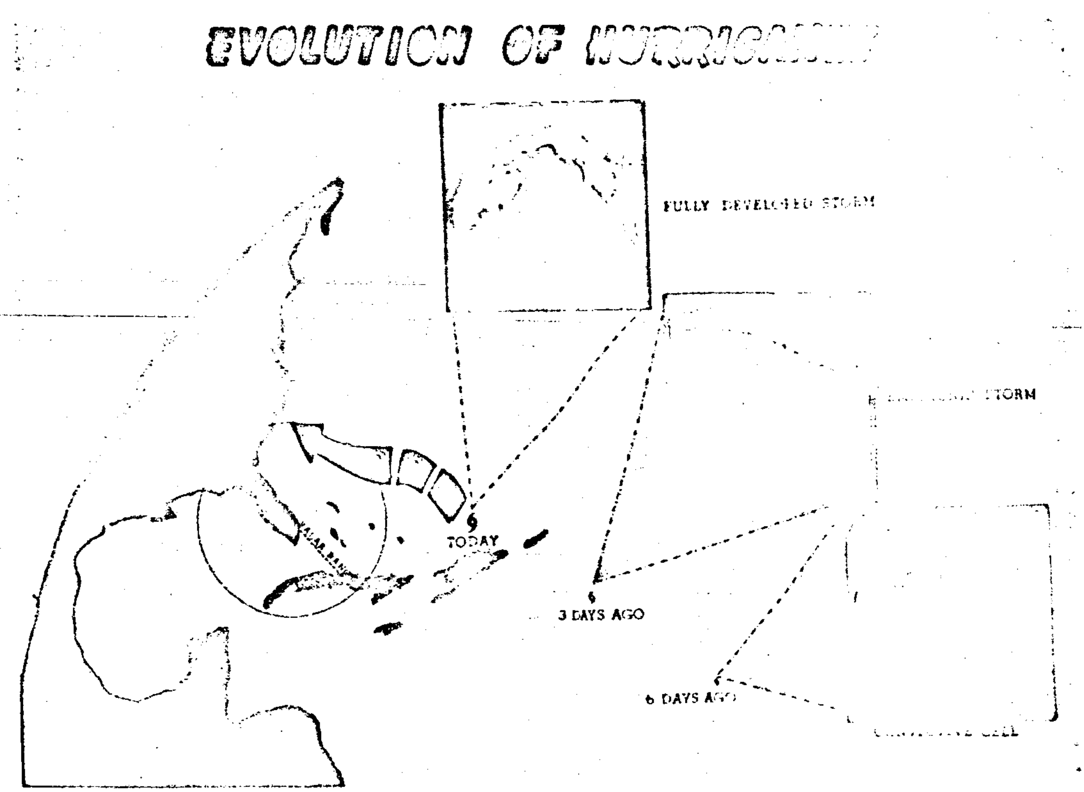


FIGURE 4

from one of a number of small convective cells of diameter 40 to 50 miles to the embryonic spiral shown in the next stage to a full-fledged hurricane. Of the hundreds of such convective cells that may be present at any one day over the tropical oceans, weather satellites may help identify that particular one selected to grow into a hurricane. Then weather airplanes could be dispatched to obtain more information. When such storms are detected in their very early stages of growth before they have acquired much energy, the possibility enters of preventing their further growth into hurricanes or of diverting them. But to do this, we must know more about hurricane formation and movement, and satellites will serve as valuable diagnostic tools as well as early warning patrols.

We now come to a smaller but much more ferocious type of storm that afflicts this area, the tornado "twister." In figure 5 there is shown a bright isolated "square" cloud, about 100 miles on a side, observed by TIROS I east of the Texas panhandle at 2 p.m. local time on May 19, 1960. This cloud apparently is an amalgamation of several individual "anvil-top" or cumulonimbus clouds associated with thunderstorms. Within the next three hours, reports were received of hailstorms at Hobart and Ft. Sill, Oklahoma, and seven tornadoes within a 50-mile radius of Oklahoma City. Of the scores and hundreds of thunderstorms that may be present over the midwest on a hot spring afternoon, why do some develop tornadoes and severe wind storms? Evidence is growing that the "mother" cloud of such severe storms may be isolated from other cloud masses in some characteristic pattern. We shall, I am sure, find weather satellites increasingly useful in the detection of tornado-producing clouds.

We shall now go from the very small to the very large, realizing that local storms, fronts,

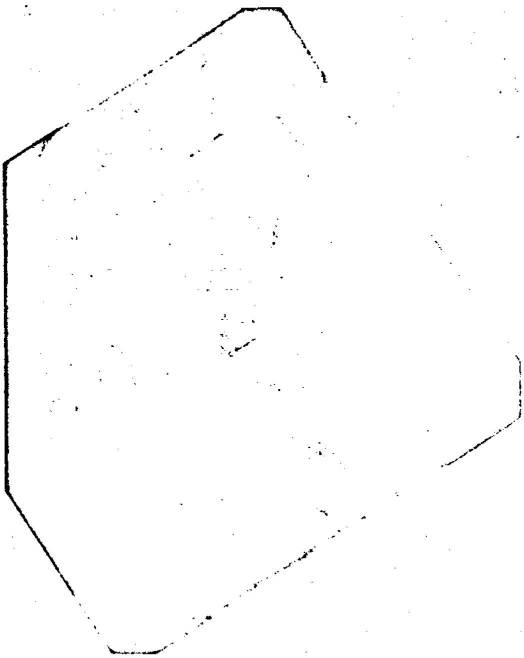


Figure 5

and jet streams are but part of a world weather pattern. In figure 6, examples of actual clouds observed by meteorological satellites have been combined into a hypothetical world cloud chart. When such cloud maps, combined with other weather measurements, are available daily, we can keep track of world weather, note variations in storm tracks and frequencies, and see how unusual weather patterns in various parts of the world are connected. Also, clouds themselves are extremely important in the maintenance of our present climate, since their high reflectivity to sunlight serves as a natural thermostat to keep the world temperature within narrow limits. A larger than average cloud cover can reflect more solar radiation, cool the Earth, and thus reduce convection currents and cloud cover. A smaller cloud cover will enable more solar radiation to heat the Earth's surface and cause more convection and clouds. The average cloud cover over the Earth is about 50 percent, and the average Earth reflectivity or albedo is 35 percent. A 1-point increase in cloud amount causes a 0.4-point increase in albedo, which, by reflecting more solar radiation back to space, means a decrease of world temperature by 0.7° F. A system of meteorological satellites could keep track of variations of the world's cloud cover as the first step in deciding whether man is having a noticeable effect by causing condensation trails from high-flying jet aircraft, for example. Understanding why world weather behaves the way it does will be the first step in trying to introduce beneficial modifications. Present conventional observing systems only probe about one-fifth of the total world atmosphere. By observing clouds, radiation currents, and other phenomena with the help of meteorological satellites, we could keep a continuous watch of any important atmospheric disturbance. These observations, fed into mathematical models of the atmosphere based upon the laws of physics, could enable us in future years to predict what the effect would be of man's attempt to change some of the basic parameters such as changes in reflectivity of large portions of the Earth's surface by artificial clouds or other means.

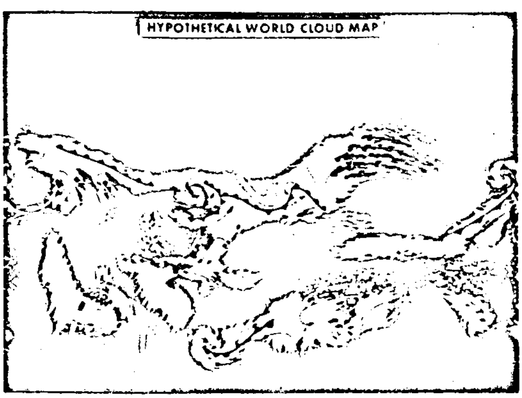


Figure 6

To really serve the needs of meteorology both from a prediction point of view and also for better understanding of weather patterns and their possible modification, a meteorological satellite system such as the one illustrated in figure 7 will be required. This is composed of two types of satellites, those orbiting from pole to pole and those more or less stationary at predesignated spots over the equatorial zone. Both types of satellites would send their observations into a central weather office via readout stations and would also serve as meteorological communication satellites by picking up information

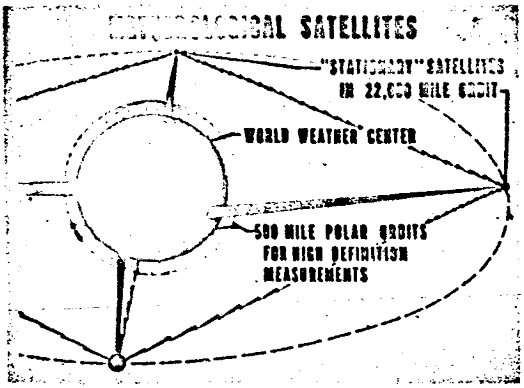


FIGURE 7

from automatic weather stations located in uninhabited areas. All these observations would then be processed at the Weather Central and the predictions relayed back to local forecast offices through the same system of combined meteorological and communications satellites. Meteorologists feel that they must rely heavily on communication satellites in order to handle the heavy traffic load which for present conventional meteorological data over the world daily amounts to almost a million 5-digit words of a highly compressed meteorological code, most of which must be transmitted speedily to scores of major forecast offices. With satellite data and other expanded observations, this load will be increased considerably. Since weather information for prediction purposes is highly perishable, there should be minimum delay between the observations and receipt of the forecasts by the users.

It is quite apparent from the foregoing that the advent of meteorological satellites will have a strong impact on operational and research meteorology throughout the world. In the framework of international cooperation in meteorology extending back 83 years, the appearance of meteorological satellites presents some novel aspects and opportunities. First, in contrast to most conventional observing stations, the satellite observatory is not at a fixed location in the home territory or on the high seas. Earth-orbiting satellites are truly global in their range and thus enable the meteorologists of the launching country to observe atmospheric phenomena over their area and outside areas, more rapidly and more completely than can be done by local meteorologists, and to make some measurements that cannot be done at all by conventional means no matter how dense the station network is. Since some of the phenomena observed by meteorological satellites may have rapid and serious consequences to the safety of the population and to the economy of a nation, it is imperative that meteorological-satellite information be conveyed speedily to all the nations. This might be done in several ways:

(1) Readout of data by the launching country, which relays data summaries on international meteorological circuits by means of coded messages or by facsimile. This system of notification introduces delays of several hours, which may seriously limit the value of the information.

(2) Readout of data by individual nations or groups of nations. This would seem to be the most efficient way of disseminating such information and putting it to immediate use, but may involve rather expensive equipment of the order of 3 million dollars or more per receiving station and would complicate the satellite instrumentation if all data were to be transmitted in this manner. A more realistic possibility would be the continuous transmission and local receipt of some of the data, such as cloud pictures over a limited area, with the remaining data being received and processed at a central location before international transmission.

(3) Communication satellites. Here the launching nation could receive the information from its readout stations and transmit it in digested and analyzed form to other nations via communication satellites. Raw information from meteorological satellites might also be relayed via communication satellites directly to central processing centers not in line of sight of the meteorological satellites.

A beginning has been made in limited international release of meteorological-satellite information from TIROS II. Whenever meaningful data were obtained for the southern hemisphere, these were transmitted by word message to the International Antarctic Analysis Center at Melbourne, Australia, where meteorologists of several nations are cooperating in studying the meteorology of a major portion of the southern hemisphere. Also daily transmissions of cloud charts by U.S. Navy radio facsimile were beamed abroad for fleet units and received by other nations within range of these transmissions. The World Meteorological Organization informed its member countries of these transmissions and provided pertinent communication information.

The observations obtained from the operational meteorological system will also be used by research meteorologists in improving their understanding of world weather, climatic changes, and possible paths leading to beneficial weather modification. World Data Centers, which gather and disseminate meteorological data for research purposes by all meteorologists, would also receive satellite data. World Data Center A, run by the U.S. Weather Bureau at Asheville, North Carolina, is now receiving and distributing to universities and meteorological services here and abroad cloud photographs from U.S. meteorological satellites and will soon do the same for radiation data.

Thus, meteorological satellites represent the first and probably most important practical application of man's thrust into space and should pave the way for increased cooperation among the nations of the world.

APPLYING SPACE SCIENCE TO COMMUNICATIONS, WEATHER, AND NAVIGATION

8. NAVIGATION BY SATELLITES

by HENRI BUSIGNIES*

When the organizers of this very good meeting asked me to participate, I intended to discuss some aspects of satellite communications, as we have been working in this field for the last couple of years. Our distinguished chairman called me a little later and said that he wasn't short at all of material on satellite communications and he would rather have me talk on some other aspect of space electronics—and of course I very willingly consented.

In the early years of radio when I started working on radio navigation systems, we had the opportunity to develop the first automatic radio compass for airplanes and the instrument landing system, which is now the standard of the world, and later the Tacan system and some of the Vortac system. It is interesting to recall that a little more than 30 years ago there was not one single radio aid to navigation on an airplane or available; the airplanes were just flying without any radio or electronic assistance at all. Comparing with the present situation now, and the extensive use of electronics in airplanes, missiles, and satellites, you will agree that a fantastic revolution has taken place. But something even more important took place also. When about 30 years ago we were trying to interest pilots, the airlines, and whoever was involved in aids to navigation from the ground, we really didn't get any sympathic response at all. A typical kind of response at the time was: "You don't think we have enough trouble flying these airplanes through the clouds and the fog and you still want us to carry that thing on board. We will throw it overboard at the first opportunity."

*Vice President, General Technical Director, International Telephone and Telegraph Corporation.

I assure you this remained the situation for quite a number of years; there was no long-range program of 5, 10, or even 15 year consideration of what should be done as we witness nowadays. So this is also a revolution; and for those who have lived through these changing times, it is very illuminating and rewarding to see the recognition and understanding of what must be done to maintain our leadership and particularly of the lead-time factor. We must work now on what will give us that leadership then. I hope and I am sure that you welcome the change too.

Before the satellite era, early navigation by radio meant that an airplane or a ship at sea would get a bearing on a radio transmission either by direct observation of the direction of the waves or through a directive ground system. Later distance measurements were added as a result of the invention of radar, prior to the last war. Not only we could get direction information with the radio waves but we could get the distance of a transmitter or of an object producing an echo. It resulted in the determination of distance by hyperbolic systems by radar and by DMET which is being installed now in the airplanes of the airlines, the military having used it for many years. The accuracy of the DMET is of the order of two-tenths of a mile. Direction and distance measurements make use of two basic characteristics of radio waves: (1) straight-line propagation (2) constant speed. There is a third basic characteristic of the radio waves: the frequency; you will see that in satellite navigation the frequency became the very important additional parameter. There is another method of navigation that you may have heard about lately, because it is used in missiles: it is inertial navigation. Any movement of yourself or of any object involves using some inergy with directional characteristics. If you measure this energy and its directional application, you will know what movement has taken place. A peculiarity of inertial navigation is that errors increase with time and that you have to check your position at regular intervals, which may be of the order of minutes in some cases or hours in others.

The point we want to make is that a navigation satellite may be ideally used to provide these checks and to reset an inertial navigation system in a ship or an airplane.

Now in the space age we are faced with an entirely new possibility. Very early, civilized people have thought of using the stars and the sun to determine their position on the surface of the earth; and, as soon as the knowledge of the time became available with accuracy, good position fixing became possible through the use of an ephemeris, which gives the position of the stars and the sun as a function of time. That is why the ships have accurate chronometers.

Then in clear weather or at high altitude there is always a way to find your position if you know the time—but under the clouds or in fog and cloud when you cannot see the sun or the stars, we cannot use celestial navigation. Next, radio navigation by radio beacons and direction finders and radar has been developed and will continue to be used because they all relate to a very definite point on the Earth—the point, for instance, where you want to finish your trip. The satellite provides us now with new interesting possibilities. A satellite can transmit a radio signal which can be observed on the ground. You see immediately that by measuring the angle at which, at a known time again, you can see this satellite at least at two successive points of space, you could with a "satellite ephemeris," which tells you when the satellite passes over definite points of the Earth, determine your position the same as with the stars, the difference being that this little star moves very fast and that fact complicates the life of the users. In fact it is quite difficult to publish an ephemeris of satellites because they move that fast and, for reasons that may not be completely understood yet, they are subject to small variations and shifts of orbit. If you want to use a satellite by knowledge of its orbit, you constantly measure this orbit and send that information to the observer; if an accuracy of a fraction of a mile is wanted, every 12 hours at least, a set of measurements should be made and made available to the users. This is true for the use of any satellite for navigation, be it the one I just mentioned which can be followed with a very sharply pointed antenna or the one designed for Doppler effect observation.

The Doppler effect is something you are all familiar with: when driving at a fair speed and passing a car coming in the opposite direction whose horn is blowing, you hear the very characteristic change of tone from high to low pitch when it goes by you. This is the Doppler effect on sound waves. When the two cars are at a minimum distance from each other the exact frequency of tone transmitted is heard for a very short time, of course. If you apply this to radio waves, the only difference is that the speeds have to be much greater because of the much higher speed of radio waves. The speed of the movement with respect to the speed of the radio waves (186,000 miles per sec.) must be a quantity which can be observed. When the first sputnik was orbited by Russia, some of the U.S. scientists started to measure frequency Doppler shifts in order to determine its orbit. They were completely right of course, and I wish to mention the names of the scientists from the Applied Physics Laboratory, Johns Hopkins University, who did this work: Dr. W. Guier and Dr. George Weiffenbach. This was pioneering work; the orbit of the sputnik was calculated from frequency shifts observation when the satellite passed over. Later Mr. McClure, also of APL, had the excellent idea of reversing the process: If an orbit can be determined by this method, then if the Doppler shifts are measured at an unknown position and the orbit known, we can calculate that position. Of course, this was quite correct, it constitutes the basis of the Transit navigation satellite of which you have seen some good descriptions in this exhibition. This was supported by the U.S. Navy with cooperation of NASA at the Applied Physics Laboratory; we had the interesting opportunity to participate in the work necessary for the tracking of the satellite and the determinaiton of the orbit, and also in the development of some measuring equipment necessary to do this determination.

Let us mention briefly some of the important parameters in the Transit satellite system. The orbit has to be measured regularly. You cannot print an ephemeris and send it to the users every 6 months. This orbit determination needs to be done regularly and changes communicated to the users. The scientists solved the problem by sending the information they collected about the orbits to the satellite, and the satellite itself in turn would broadcast it to the users every 2 minutes. So when you observe the satellite Doppler shift, you also get the latest information about the orbit. The knowledge of the time very correctly is also mandatory so that the time at which it passes at the shortest distance to your position is known accurately. The Transit satellite transmits to the user the latest time correction on its time signals. Every 12 hours the latest information is given the satellite for retransmission every 2 minutes to the ground users. The advantage of the Doppler system over the sphereographical results from the simple receiver which does not involve a directive antenna. The receiver measures the change of frequency with respect to the corrected frequency transmitter by the satellite itself, and a relatively simple digital computer calculates the position of the user for him. One interesting thing: If you are on one side of the orbit or on the other, you would observe the same Doppler shift and therefore do not know on which side of the orbit you are.

This is completely true only in the case of a fixed Earth, but as the Earth moves inside the orbit of a satellite during the measurements, there is enough of a frequency shift due to the rotation of the Earth itself to permit the observer to determine whether he was on one side or on the other. This is an additional benefit freely obtained from the rotation of the Earth that our ancestors did not think of.

The illustrations (figs. 1–4) are self-explanatory and show the advantages of the Doppler systems over the sphereographical, the main parameters of the Transit system, the block diagram of the receiving system, and some typical Doppler shifts.

The sphereographical satellite navigation requires a satellite transmitter, a highly directional ground antenna, a receiver, and a clock; a vertical reference is required also. For Doppler satellite navigation a stable frequency satellite transmitter, a sensitive receiver, a frequency reference, and a clock are required,

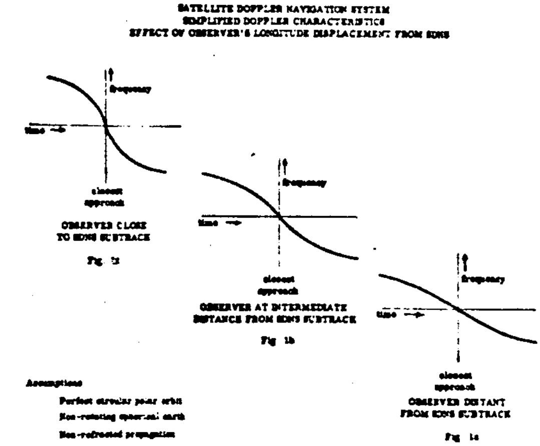


Figure 1

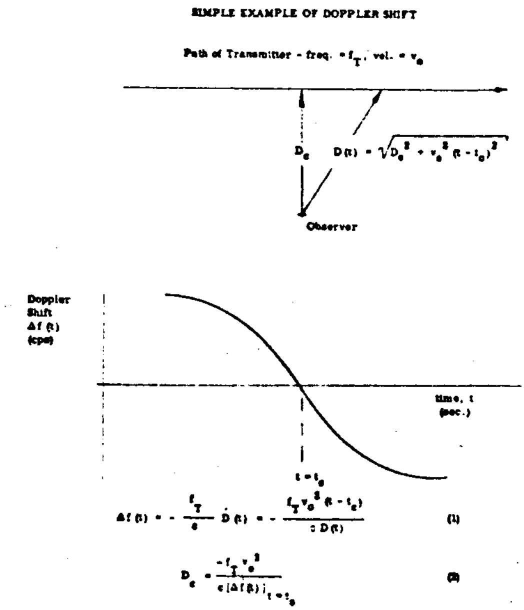
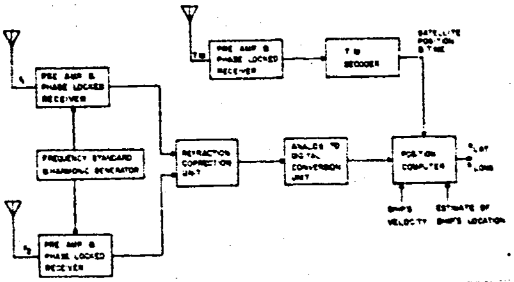
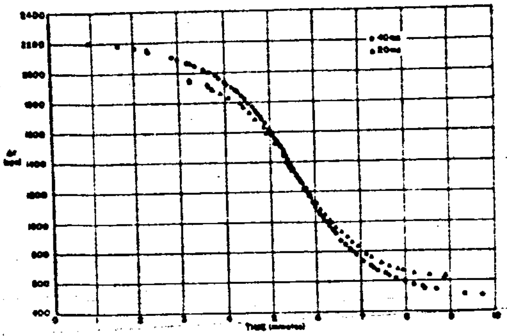


Figure 2



AN OPERATIONAL SHIP BORNE NAVIGATIONAL STATIONS

FIGURE 3



EFFECT OF IONOSPHERIC REFRACTION ON DOPPLER SIGNAL

Experimental Observations on radio signals from Sputnik II for 11/8/57, with t = 0 at 2 13pm local time. The 20mc Doppler frequencies were doubled, and the curves adjusted to make their points of symmetry coincide. It is estimated that $f_c F_2 \sim 12$mc for this pass.

FIGURE 4

but there is no need for any vertical reference or any large directive.

Many more observations have been made since those of Sputnik II in 1957. On the Transit satellite, the new Transit navigation system will be in operation early and may be the first operational satellite application. It would consist of two satellites in a 67½ degree orbit and two in a 22 degree orbit at about 500 miles altitude. A high altitude satellite is not wanted because the rate of change of frequency is not large enough for accurate observations. A low altitude is desired but not too low because there is a disturbing effect. Radio waves are going in a straight line and at a constant speed except when they go through the ionosphere, where they may be affected very seriously. We begin to know well the law which affects them; the higher frequencies are affected less than the lower, but to be practical about it it has been decided that frequencies in the range from 50 to 300 mc should be used. By using several frequencies instead of one and observing several Doppler shifts, corrections for the ionosphere effect can be made with sufficient accuracy because we know the law of variation of the ionosphere effect as a function of the frequency. Future systems will always transmit several frequencies. The order of fixing accuracy that is expected, which has been verified already and which is fully expected in a final system, is better than half of a mile. Four satellites would permit the determination of position between two- to three-tenths of a mile at any place over the Earth every one and a half hours. A fast moving aircraft would not be in a position to take full advantage of this system, but certainly all ships could.

Someday more satellites may be added and the rate of observations may be increased. A combination might be made in the future of satellites for communication and navigation which would provide observations at a higher rate. The system covers the entire Earth, and that is one of its unique features. When moving yourself, like as on a ship or a plane, a correction may have to be made for your own speed. The field of navigation by satellite is one where the United States is leading completely and I am sure will continue to lead. The Transit program will provide for a navigational system covering the whole world without any charge to the user, a most important service for all the nations of the world.

APPENDIX

TRANSCRIPT OF CONFERENCE PROCEEDINGS

MAYNARD E. PETERSON
Conference Reporter

TRANSCRIPT OF CONFERENCE PROCEEDINGS

MAY 26, 1961
MORNING SESSION

MR. D. J. TEUPKER. As President of the Tulsa Chamber of Commerce, one of the sponsors of this conference, it is my pleasant duty to call this conference to order. We in Tulsa and in Oklahoma are proud to share with you this conference and this discussion. Yesterday, you heard our mayor; you heard Senator Kerr. They gave you the official welcome of Tulsa and Oklahoma. We are happy to share that welcome with you today. I would now like to present the General Conference Chairman, who will preside during all the conference meetings. He has done a great job. He's lived this program; he's done a terrific thing in organizing it. Mr. Harold Stuart, your General Conference Chairman

Chairman HAROLD C. STUART. Thank you, Pete. I appreciate the fact that you have set the pace with short introductions. This will be our pattern from now on.

It is my great, great pleasure to introduce my boss, the Governor of the State of Oklahoma, Governor J. Howard Edmondson.

GOV. J. HOWARD EDMONDSON. Chairman Stuart, Senator Kerr, distinguished guests. It is my pleasure to welcome all of you to the State of Oklahoma. In our 53 years of statehood, Oklahoma has achieved a notable list of firsts. With the opening here today of the First National Conference on Peaceful Uses of Space, we proudly add another first to that list. Its subject matter is as timely as tomorrow's headlines. Its theme is representative of mankind's fondest hope, peace. Its opportunities for industry and for our coming generation are wonderfully suited to Oklahoma's abilities and youthful spirit. To you of NASA, to the industry leaders, the students, the faculty members who will take part in the conference, and to the Tulsa Chamber of Commerce for taking on a tremendous responsibility in sponsoring this, the State of Oklahoma says: May this conference be more fruitful than your fondest expectations. Thank you very much.

Chairman STUART. Thank you, Governor Edmondson. Now, a man whose interest in this conference is twofold, as a Senior Senator, a United States Senator from Oklahoma, and as Chairman on the Committee on Astronautics and Space Sciences of the Senate, has a word of greeting for you. You will hear from him more fully today at noon, but I am pleased to introduce to you Senator Robert S. Kerr.

Senator ROBERT S. KERR. Thank you very much, Harold. I thank each and every one of you who have traveled here to Tulsa to this First National Conference on the Peaceful Uses and Development of Space. Now, to those of you who were here yesterday, you recall that I welcomed you to Tulsa. That was the official welcome. Today I give you the unofficial welcome to Tulsa. The official welcome was cool and impersonal. The unofficial welcome is warm and personal.

We hope that we may in some manner and some measure be of help to each of you that has journeyed here to Oklahoma to be with us. I want to tell you quite frankly that, while we hope to be of help to you, we expect you to be of help to us. We do not believe that there has ever been such a transfusion of brain power, inspiration, technical knowledge, scientific leadership injected into the bloodstream of Oklahoma's thinking, psychology, and economy as your visit here and your participation in this conference will amount to. We believe that it will be of great impetus, a great stimulant to us. While we are aware, and hope that you become aware, that you are now in the greatest social, economic, healthful environment available to an American citizen in any state in the Union, we believe that you will be aware of that and that your visit and journey here will make it even better, and it just might, who knows, either demonstrate that what I have said is true, or by reason of your contribution you might make it so. Thank you, you are sure welcome in Oklahoma.

Chairman STUART. Thank you, Senator Kerr. Now, ladies and gentlemen, we will receive a personal greeting from the President of the United States.

[President Kennedy's welcome was then broadcast.]

Chairman STUART. The morning and afternoon sessions today are devoted to one subject: NASA Space Flight Programs. To serve as your chairman today, I would like to introduce the Director of Space Flight Programs for the National Aeronautics and Space Administration, Dr. Abe Silverstein.

Dr. ABE SILVERSTEIN. There are many who have questioned: "Why this space effort?" Now, requiring, as it does, the most advanced science and the most advanced technology, the results achieved in our space effort are in truth the measuring stick of our national competence and capability. Our achievements are measured by the whole world. Unlike our technical accomplishments which this nation has contributed in the nuclear systems and in other weaponry, our successes and our failures in development programs in the space-flight arena are viewed by all and they are evaluated.

Yesterday, we had a heartening message from the President from which I will quote, and he says, "Now is the time to take longer strides, time for a great new American enterprise. Time for this nation to take a clearly leading roll in space achievement." And he went on to say: "For while we cannot guarantee that we shall one day be first, we can guarantee that any failure to share this effort will make us last." He said, "But this is not merely a race, space is open to us now, and our eagerness to share its meaning is not governed by the efforts of others. We go into space because whatever mankind must undertake, free man must fully share. Space is the new frontier in our technological age. It is challenging and demanding and requires the type of growth in all areas of science and technology that will provide a focus, that will provide a catalyst for the stimulation of our universities, their students and faculties, our industry, our governmental laboratories throughout the country. The increased knowledge accrued will spread and diffuse to the whole fabric of our society and provide the stimulus for a lively growth and a better way of life for all of us."

I think it is particularly appropriate that this conference deals with the peaceful uses of space, for I believe there is hope by peoples throughout the world that space will not be used as another battlefield. It was the intent of Congress in establishing NASA in 1958 that our efforts would be directed toward the peaceful uses of space for the benefit of all mankind. And it has been with this intent that the program that we bring you here today, to review, has been developed. The emphasis placed in this program on science is based on the applications of space technology for the uses of man and is placed on manned space flight. Now, in support of these primary missions, we have our advanced technology for development of the space vehicles and of the spacecraft that are required to carry them out. Now, in our program this morning, we will have four papers; and in the program this afternoon, we will continue with four more papers that will present segments of our program to you. We start this morning with a review, a general review of the area of science, paper to be given by Dr. Robert Jastrow, who is Chief of the Theoretical Division at our Goddard Space Flight Center, Greenbelt, Maryland, and also Director of the new Institute for Space Studies that was recently established in New York City. I call on Dr. Jastrow.

[Papers by Robert Jastrow, Edgar M. Cortright, DeMarquis D. Wyatt, and George M. Low were then presented.]

AFTER LUNCHEON

Chairman STUART. Ladies and gentlemen, this session of the conference is to be devoted to industrial and educational implications of the space program. Following the principal address, four panelists will present their views, and there will be closing general discussion. May I introduce the panelists. First, the President of the Douglas Aircraft Company of Santa Monica, California, and Tulsa, Oklahoma, Mr. Donald W. Douglas, Jr., from Douglas.

The Executive Vice President of Frontiers of Science of Oklahoma, and the Dean of the College of Education at the University of Oklahoma, Dr. James G. Harlow.

The Vice President of Burtek, Inc., of Tulsa, Oklahoma, Mr. John H. Koch.

The Dean of the College of Petroleum Sciences and Engineering of the University of Tulsa, Dr. Scott W. Walker.

Now, to introduce the principal speaker, I would like to present the President of the Tulsa Chamber of Commerce, Mr. Teupker.

Mr. D. J. TEUPKER. Ladies and gentlemen: I present to you a leading advocate of land, wood, and water. However, today I am going to present him in a new role; but in case you do not think that he is an apostle of land, wood, and water, we would invite you to tour the reservoirs of Oklahoma and see the wonderful water development that his leadership gave to Oklahoma. Yesterday, he spoke to you, as he said this morning, formally, but he spoke with authority. Today, he will speak with authority again, because he is Chairman of the Committee on Aeronautics and Space Sciences for the United States Senate. Following his address, which will be concerned with industrial and educational implications of this national space effort, he will serve as Chairman for the panel discussion which follows. I take a great deal of pleasure in presenting the distinguished Senator from Oklahoma, Robert S. Kerr.

Senator ROBERT S. KERR. Well, now, as they say, the third time is the charm; we will find out. I tried to fortify you this morning with the hard grind of the day. I am now about to test you out to see how well I did it.

[Address by Senator Kerr was then presented.]

Chairman STUART. To proceed on with our panelists, I will first call on Mr. Donald W. Douglas, Douglas Aircraft Company.

[Papers by Donald W. Douglas, Jr., James G. Harlow, John H. Koch, and Scott W. Walker were then presented.]

AFTERNOON SESSION

[Papers by Milton B. Ames, Jr., Alfred M. Mayo, Harold B. Finger, and Wernher von Braun were presented.]

[Address by James E. Webb was presented at evening banquet.]

MAY 27, 1961
MORNING SESSION

Chairman STUART. Good morning. Welcome to the second session of the First National Conference on the Peaceful Uses of Space.

I would like now to introduce your Chairman for the morning panel, Mr. L. A. Hyland, Vice President and General Manager of Hughes Aircraft.

Mr. L. A. HYLAND. Certainly, the timing of the man-in-space part of this program is ideal in the light of the President's announcement that we are going to enter the race for the first Moon landing and return. And I think it's particularly appropriate that we have the men associated with this panel this morning who have to date laid the foundation for the work that is to go forward in the "man to the Moon and back" race, and who can give us not only their experiences that have been achieved in the space capsule but also lay the foundation for what we hope to see in the next nine or ten years.

Leading off the discussion this morning is the man who is perhaps doing the most in the transition work. The leading off from the wing-supported type of craft, getting into space and finding out much of the information that we will be using in our future astronaut programs. Mr. Bikle has a very unusual capability, not only as an engineer in the manned flight program, but also he happens to hold the world's record for gliders, and I think that you will find that what he has to say with respect to the X-15 program will be a very good foundation for what's to follow. I am not going to spend any time reading the biographies of these gentlemen: you will find them contained in your program, and I am sure you would much rather hear the messages that they have to bring to you. Mr. Bikle.

[Paper by Paul F. Bikle was then presented.]

Mr. L. A. HYLAND. We are going to confine our questions to the period after the speakers each have an opportunity to present their information. The next speaker has presented me with this space-age gavel made in the form of the Mercury capsule, and, as you may suspect, it comes from Mr. McDonnell of the McDonnell Aircraft Company. Actually, this will be a double-barreled presentation by Mr. McDonnell and Mr. Burke, Vice President in charge of the Mercury Capsule Project. Mr. McDonnell perhaps is one of the most stimulating members of the Aircraft Industries Association, and we always enjoy his very pertinent and effective remarks in our meetings. He has done an enormous job in leading and solving the problems associated with the Mercury capsule, and I am sure that you would like to hear from him and Mr. Burke directly.

[Paper by J. S. McDonnell was then presented.]

Mr. L. A. Hyland. I think the job that McDonnell did in this area has been tremendous. About a month prior to the first space flight, I was a member of a panel from the President's Science Advisory Committee to make a survey of the man-in-space program, the Mercury project, and observe whether it was really ready. And several of us spent a week studying with Mr. McDonnell and working through by gradual degrees to Washington. We determined that the project had been done. I think there was one other determination that we came to, and that was the importance of one man in this project. And the man-in-space program, the Mercury program, is much broader than just the space capsule. It comprises an around the world communication and safety program. It results in spotting ships at various places and making provisions for every possible contingency that can happen to the astronaut. It embraced a large training program over a couple of years. We had to really explore in many different directions. There was one man who kept this all in a state of balance, who made the difficult decisions, the difficult compromises that have to be made on any major engineering program. That one man is Bob Gilruth, who will now speak to you about the direction of the program, and I want to introduce him with a bow.

[Papers by Robert Gilruth, W. R. Lovelace, II, James R. Dempsey, and O. J. Ritland were then presented.]

Mr. L. A. Hyland. I think that you can gauge the caliber of the panel members by the remarks that they have made this morning. I think that you will agree with me that we have indeed laid a very solid foundation in very diversified areas. And that we have the capability of a future plan that can bring the United States to a pre-eminent position in space, but one impression that I do not want you to leave with today is that that all is yet in order in the space area. The President's speech, of course, was extremely encouraging, because it does indicate that there is in the administration for the first time a clearcut recognition both of the need for the scientific information and the need for the prestige associated with psychological warfare in the space area. Also, for the first time I think we have stepped up and recognized the staggering cost that is going to be associated with the space program. There doesn't seem to be much question that at least thirty-five billion dollars over the period of the next eight or nine years is going to be necessary for the lunar-landing program alone, and this is a tremendous assignment. It's a real tough job to spend a billion dollars and spend it wisely, and it takes a lot of people and a lot of coordination and organization. And one thing that I want to bring out particularly is that the space program and the new funds to be allocated that are now being talked about should not be regarded as a panacea for industrial unemployment or a pork-barrel operation for either industry or science; and that this puts a real requirement for single-agency planning, or if not single-agency planning, a central planning agency in order to control our space program; that we have simple points from which we want to develop a program, conduct research and developments leading to the achievement of that program. One of the things that is almost fundamental in industry or in government is that management should assist in the accomplishment of an objective and not put hurdles in the way. But we have many, many interfaces in the technical parts of the space program, but we have got a lot of interfaces in management right at the present time. One of the points that we examined in the Mercury program to see whether it was ready to go was whether or not there was adequate cooperation between the several Services involved, and I am happy to report to you that despite all of the barriers that have been put in the way management-wise, because there were many agencies within NASA, many agencies within industry, three Service agencies involved, plus the State Department and all of the other facets of the picture, there was collaboration and people were doing something in spite of organization rather than because of it. And they did work together to do this job. But as we are getting a bigger job and a more diversified job, the need for control, for planning, for focusing on objectives is much greater than it has ever been before. Good will isn't enough.

Now, there is another aspect: While we have a diversified program, while we are producing a great deal of scientific information, we have to admit realistically that we are doing it because we can't do more. We have nothing to match the lunar hit. We haven't had anything to match the lunar orbit, which was the next stage. The Venus shot was a real scientific achievement; and we can't do any of these things yet and we are not going to be able to do them if we keep spreading our shot, using a shotgun approach instead of a rifle and not putting the emphasis on a single objective and a single coordinated planned program without all of the difficulties associated with many managements that we have today.

I think, too, that we want to make more ultilization of the skills already established, that as each new program comes down the line, the objective is not to bring a new agency into being or create a new laboratory, or to bring new contractors into the field and not utilize the information that we already have. So, there is much to be done. There is much to be done on a control viewpoint. There is much to be done technically. And I think that we have all got to put our shoulders to the wheel. We have all got to work for these uniform objectives. And only in that way can the United States in ten years, perhaps, pull equal or perhaps forge ahead in this prestige area and practical area of space.

Now, we come to the question program, and I am sure that you folks will have many things to ask of the panel who have been appearing before you this morning.

Dr. Richard W. Poole, Oklahoma State University. I would like to address a question to McDonnell. I understand, Mr. McDonnell, that your company has adopted the policy of donating the full five percent of corporate profits for the promotion of education. In this connection, I would like your comments on two questions. One, why do you consider this an important activity for industry; and secondly, does your support include the social sciences as well as the natural sciences, and is it limited simply to higher education or does it also include secondary education?

Mr. J. S. McDonnell. It is true that our company has for some years given five percent of our earnings before income taxes to a foundation for all philanthropic purposes. The majority of it has gone to education, but not all of it. It does have a connection with the space science and exploration. We have tried to select educational projects that had as much bearing on the physical sciences as we could, and we have felt that the conquest of space is no little thing, that it's a great big thing. And to carry out concurrently the program which is the purpose of this particular conference, the conference on the peaceful uses of space—which historically is a very large effort for the human race—but then to concurrently maintain a foundation of military strength on land, at sea and in space, and in the air, that foundation is necessary so as not to let down our guard the way we did after World War I and World War II, in order to prevent big wars. On that kind of solid foundation, I would hope that the peaceful conquest of space could take place and that as much of the competition between the free world and the Communist world channeled into that peaceful conquest as possible. But we can't control how much the Communist world will challenge in that direction. But by the way that they have so basically challenged us there and then rubbed it in, to our mortification at times, would indicate that they do plan to make that a very major effort. Now, to do all of these things concurrently cannot be done on the foundation of education we have now. It means rearing our kids with sterner discipline and with better education all the way from kindergarten clear through graduate schools. And looked at from the standpoint of the next century, and I think we should look at it from the standpoint of the next century, it's going to take a massive increase in education, both in quantity and in quality. Now, how can it all be financed? We can leave it up to the Government. We have seen in the present Congress a strong response to that need, but is it wise in our system of freedom to leave the major portion of it up to the Government? There are a lot of us who feel that wouldn't be wise, so where will all of the other money come from? It could come by every corporation setting aside for educational philanthropic purposes, five percent of their income before income taxes in every year when they have earnings.

The time to do it is when you have earnings, because if you start doing these things and then you give nothing to the educational activities in the years you don't have it, your public relations will be worse than if you never started at all. So it is helpful to have a foundation to give it to. Now, on the private side, Congress in its wisdom has encouraged people to give, as allowed by an Act of Congress, up to 20 percent of their private income before income taxes. Now, Congress also allows to give up to the 30 percentile, provided the 21 through 30 percentile is given direct in that year and not through a foundation to an educational system and two or three other kinds. I have found that's very difficult to do. You just can't work up the project soundly. I would hope in the years to come the Congress would allow that up to 30 percent without that kind of restriction. I would hope that in the years to come that Congress would increase for corporations the amount deductible from 5 percent to 10 percent. If this be treason, why, I am ready to stand up and be shot; thank you.

Mr. Neal E. Van Fossan, Sr., Engineer, Union Texas Natural Gasoline Corp. I would like to address a question to Mr. Dempsey. We are all perturbed that the Russians appear to be ahead of us. Do you attribute this solely to their advantage in heavy boosters?

Mr. James R. Dempsey. No, I attribute it to their advantage in the decision-making process.

Mr. Neal E. Van Fossan, Sr. Their ability to make a quick and direct decision, or to implement the decision?

Mr. James R. Dempsey. Only to make a decision as to what they are going to do and then stick with it to see it through. It's something that we have not so far in this part of our programs been able to do in this country. There is some hope that we might now. We will await with interest to see if we are able to do this.

Mr. John W. Herrick, American Aviation Publications, Beverly Hills, Calif. I have a question for General Ritland. I notice that most of the Air Force program's dealing with manned and space winged vehicles and what we call lifting reentry. Is there any reason why the Air Force is not working or programming into force this emergency program?

Maj. Gen. O. J. Ritland. Well, I believe that working closely with the NASA, they have the ballistic reentry program and we have been working on Dyna Soar with the winged vehicle. As we progress further into the future and especially as we go into lunar exploration, we would probably combine our technical resources and come up with a single vehicle. You must remember that we in the Air Force are participating with NASA not necessarily on the vehicle itself, but in the booster area and in the Dyna Soar program NASA is participating with us. I would rather place it as a national effort that we are all doing, and duplication when required is certainly necessary, but in this particular case, as of this time I don't believe it is necessary.

Mr. Dick Charles, KVOO Radio. I would like to address this question to Maj. Gen. Ritland of the United States Air Force and to Dr. Lovelace. I am told that the Russians have an educational program whereby they weed out their youth at the beginning of their education program and set them apart to become certain things and that's what they become. I am wondering in the space age if the United States will take an individual and give him an I.Q. test, say when he enters the first grade, and set him out on a steady program and that will be what he follows, or will we continue to have somewhat of a free choice of our own studying and best wishes and dealings and beliefs.

Dr. W. R. LOVELACE, II. In the Russians' educational system, they do, as you are probably well aware, give these intelligence quizzes and they do direct what particular area they think a particular student should go into, whether it be physics, engineering, mathematics, chemistry, or the social sciences. I know that one thing that impressed me was that they had a thousand post-graduate students in applied psychology in Russia. That's quite a group of men to work in an area which, of course, is the cold war area, I am sure. I don't believe we will ever use the system the Russians use. Conant has pointed out recently that 50 percent of our very intelligent young students don't go on ahead to college and to advanced degrees. If they had the funds and the opportunity, I believe that Conant's program could be followed to real advantage. I know certainly that most children in this country are a little bit difficult to argue with when it comes to what career field they are going into. But I think that the children of today are extremely interested in space and they certainly can go into space-oriented programs.

Mr. PAUL L. LYONS, Chief Geophysicist, Sinclair Oil & Gas Co., Tulsa, Okla. I would like to ask Major General Ritland an elementary question. If propaganda value is important, why do we not put a brilliant light on a satellite so that it can be easily seen any time at night when it is within range?

Maj. Gen. O. J. RITLAND. This has been done, but not probably in the power requirements where it could be seen readily. I think the Echo project by NASA was a good demonstration of that, in that it could be readily seen at certain times of the evening. I think that there are other important things that should be done in getting along in the space age that are stepping stones to our future long-range objectives. If this happens to be a part of it, it will certainly be done. But I emphasize that there have been lights on satellites and this has been on the navigation-type satellite to be sure that we can visually identify the position of the satellite versus electronic positioning.

Mr. ALLEN E. COOK, Operations Research Chief, Ross-Martin Co., Tulsa, Okla. The last question suggests this one, that I was going to ask anyway for another reason. The question of medical or physiological adaptability to space raises the question is there any racial difference likely to be found in the ability to resist radiation or discomfort or what not, and if not, what sort of propaganda or public relations activity would help the United States' appearance in the world in this regard?

Mr. L. A. HYLAND. I am inclined to think that this is a question that I would prefer not to explore at this particular time. And I think perhaps there may or may not be information relating to it, but momentarily, I prefer to duck this one.

A CONFEREE. Mr. Hyland, have there been any steps taken towards forming this committee for central planning, or do there seem to be any objections to having central planning?

Mr. L. A. HYLAND. I think there has been a great deal of activity in the last three or four months in this direction. I have been extremely encouraged in some of the steps that have been taken in the Department of Defense and in the administration leading to an examination and a consolidation of these programs. I think we have an enormous way to go yet, but nevertheless, there seems to be a will to determine the facts and to try and simplify the programs, to put the money where it would count the most, to consolidate the efforts. But since it is a big program, since there are many vested interests and a lot of history behind this, it's going to take us awhile to do it yet, but I think that you folks can leave this particular conference and spread the word that we need more of the same. I think that I would like to get the comments of some others on that. How do you feel about it, Mr. Dempsey?

Mr. JAMES R. DEMPSEY. I think the answer is very definitely "yes". The new administration has had a number of studies underway by both the Defense Department and the civilian agencies, and they have talked to each other. I believe that the announcement on Thursday would give us an indication that this will continue.

Mr. FRED N. BENNETT, Central High School, Tulsa, Okla. In the talks on the physiological aspects of space flight, I have been wondering whether or not a good deal of consideration has been given to the environment that is carried by the astronauts into their space vehicle and how to control that.

Dr. W. R. Lovelace, II. Yes, that's been one of the prime objectives of the whole program, the life-support system so-called, and it did function very very well on Shepard's flight. As the time goes on, of course, there's a question of how much pressure will be carried in the spacecraft, whether it will be 5.5 psi or 15 psi as it is here in the Earth, and whether or not it will be 100 percent oxygen.

Mr. Fred N. Bennett. May I ask another aspect of the question, please. That is, how about the disposal of undesirable waste products from the human inhabitants of the vehicle?

Dr. W. R. Lovelace, II. Well, there are research projects on that and so far, they look like they are going to be quite successful, thank goodness.

Mr. C. L. Campbell, Sewanee Military Academy, Sewanee, Tenn. Between solid-fuel boosters and liquid-fuel boosters, which do you seem to feel offers the best advantage?

Mr. James R. Dempsey. I think the answer to that is we don't know and that's why we are going to undertake building both of them. Solid propellants and liquid propellants, I think, each have certain characteristics: they are different. In some applications. solids are clearly preferable, and in others liquids are clearly preferable, and in some we aren't sure. The people who are in the systems business, I think, generally are prepared to use either in its best application, and I think that we have yet to learn which one will be best for the very large, and by this I mean perhaps booster thrusts in excess of two million pounds.

Dr. T. S. Burkhalter, Director, Materials Research Department, Central Research Laboratories, Texas Instruments, Inc., Dallas 21, Tex. I would like to address a question to Mr. Hyland. I was somewhat disturbed, Mr. Hyland, by what I thought was an implication of some of your closing remarks. I would like to explore them and have them corrected if I misinterpreted them. One of the things which I felt you indicated was a desirability for increased concentration of our efforts under a single agency and particularly an increased concentration on the single objective of a lunar flight. Does this mean that you advocate we should deemphasize such objectives as our communications satellites, weather satellites, and navigational aids?

Mr. L. A. Hyland. I'm sorry if I gave you that impression, because it certainly isn't what I want to convey. I do believe in the necessity for single agency or single grouping of the planning, so that we don't go off in fourteen different directions at once. However, you cannot any longer point up in space to one particular objective. The landing of a man and returning him from the Moon is one. But certainly, one of the objectives that we can quickly reach if we concentrate on it is a communication satellite. Right at the moment, there are perhaps three agencies involved in it and to some extent, they are working at cross purposes. By the same token, we need a considered approach to the weather program and to several other things that are achievable in the space area, but they should be tied together. They shouldn't proceed independently and they should not proceed without the interchange of information.

Mr. Percy Carr, Iowa State University. I should like to address my question to Mr. Dempsey. There have been rumors that have reached me, at least, that the Russians have been able to get their large vehicles aloft not through vertical boosts but by horizontal or inclined takeoffs. I would like to ask, do you think these rumors have any basis in fact, or do you care not to comment on the question?

Mr. James R. Dempsey. I will always comment on anything. I don't know what the Russians are doing, except what I read in the newspapers. I have not seen any intelligence briefings in a long time. I think it is very unlikely that they are using inclined takeoffs, because all this does is simply increase gravity losses and isn't necessary, so I doubt very much that they are doing anything other than a straightforward vertical takeoff.

Mr. Percy Carr. The advantage reported was that you would not have to use a rocket propulsion until after you attained rather high speeds and that part of the propulsion system could be dropped off as the thing lifted off. If this were true, how much advantage would it be worth to go to higher altitudes, say at five thousand feet above sea level for such operations?

Mr. JAMES R. DEMPSEY. Launching from high altitudes does give some improvement. One has to go to about ten thousand feet to effect, say, a five-percent reduction in the gross rate of takeoff, and this turns out not to be consistent with other requirements of launching locations, such as not flying over populated areas, things of that sort. The cost of a device which would give you a reasonable velocity increment before you would light the rocket, say a thousand feet per second, is so much more than the cost of attaining the thousand feet per second by just making that rocket a little bigger, that it wouldn't make sense.

Dr. A. B. NADEL, Psychologist, General Electric Co., Santa Barbara, Calif. Yesterday, reference was made to two specific international programs. This morning at the panel meeting, no reference was made in terms of the future of our space program with regard to any international cooperation. I'd like to ask either Mr. Hyland or General Ritland whether any of the programs, rather than specific individual projects, are not being set up for what may be an international cooperation program in space.

Maj. Gen. O. J. RITLAND. We are working with the Canadians on a certain program of a scientific nature. I think it would be the intent of the Space Council to use all of the technical capabilities of a free world as we get further into our space programs. This, of course, would be done through the NASA, and I believe that maybe Bob Gilruth could answer that.

Mr. ROBERT GILRUTH. I don't think it was brought out in any of the presentations having to do with Mercury, but I would like to take this opportunity to say that there is a great deal of international cooperation in this project, particularly in the network. We have stations, 17 stations around the Earth with cooperation from such places as Australia, where they are taking a very active role, using their own tracking facilities and people in the Mercury project. We also have stations in Nigeria and in aZnzibar; and in the conduct of this whole job, we find that we require and are getting cooperation from nations around the Earth.

Mr. L. A. HYLAND. I think that one of the missions you know—the State Department sent a message to all of its ambassadors recently in which it was indicated that they wanted to use every possible effort to collaborate with industry. Now, this, amazingly enough, was almost an extraordinary message on the part of the State Department, because the attitude of ambassadors to industry in prior years had been rather stand-offish. And I do know that one of the areas that is being considered for collaborative operations is the space operation, particularly with respect to communication satellites. So that I would suspect that since in the free world, at least, the United States has the total supply of boosters, such as they are, that there will be a great deal of cooperation back and forth in this area.

Mr. BRUCE V. KETCHAM, University of Oklahoma, Norman, Okla. I would like to direct my question at one of the three aeronautical engineers on the platform, or all of the three Mr. Bikle, Mr. Gilruth, or Mr. Dempsey. We are contemplating the construction of a space environment simulator at the University of Oklahoma. I would like to know whether you feel that this would be a practical instrument or facility for education on research purposes in the space age.

Mr. PAUL F. BIKLE. I think this would depend largely as to what extent facility it was. Most of the facilities I have seen are rather expensive, rather large scale. I think that if one could be provided that would be useful in space work, it would be a most excellent facility for the purpose you have asked.

Mr. JAMES R. DEMPSEY. I think it is just as important as the wind tunnel was 25 years ago.

Mr. JOHN W. HERRICK, American Aviation Publications, Beverly Hills, Calif. This question is for Dr. Lovelace. I know that a lot of study is being made about contamination of the Moon by Earth bacteria. Now, we are approaching this big crash program to put man on the Moon and bring him back. What about bringing Moon bacteria back to Earth?

Dr. W. R. LOVELACE II. Well, I believe in

Mr. Low's presentation, there was a discussion of decontamination before reboarding the Apollo vehicle or whatever vehicle is used, before people were to come back to the Earth. I'm sure that many of you realize that we now have drugs available, for example, that can completely sterilize the intestinal tract, that we use before we do certain types of surgical procedures on the large and small intestine. If it ever becomes necessary, we can in a large part eliminate the regular normal bacterial flow that we carry around with us. It becomes a little difficult, though, because if you don't watch it then the molds take over, and mold infections are one of the most difficult things we have to treat. Decontamination before coming back to the Earth perhaps can be accomplished by means of disposable outer garments. The work that the Atomic Energy Commission has done in their decontamination procedures, I think, would help a lot.

Mr. Donald R. Beem, Assistant Personnel Director, Adams R. & D. Consultants, Inc. I would like to address a question to Dr. Lovelace, concerning this matter of waste disposal. Would this system be purely mechanical or would we go into a biological regeneration system?

Dr. W. R. Lovelace II. Well, the biological regeneration systems have the advantage that they don't require the power that some of these other systems require. And, of course, we do have a nice hard vacuum which will kill off a lot of things that we don't want around. If you can expose the sample to the vacuums.

Mr. Donald R. Beem. I would like to ask you another question. About what is your estimation on time on a biological regeneration system? Are there any being developed at this time?

Dr. W. R. Lovelace II. They are being developed. It's an area that we haven't been working in out at our place, and I don't know what the true time schedule would be.

Mr. L. A. Hyland. Gentlemen and ladies, I think you have been very patient. I think that some of our interests are beginning to be satisfied. I want to thank you very much for your attention. It has been interesting indeed on this long session to see how many people have been on the edges of their chairs, and I think that it is really a tribute to the interest that the nation as a whole has in the space program.

AFTERNOON SESSION

Chairman Stuart. Now it's my pleasure to introduce to you Dr. Ben Henneke, President of the University of Tulsa.

Dr. Ben Henneke. It is my extreme good pleasure to be permitted to present [illegible] a gentleman who in his own lifetime has participated in the last exploration of the unknown frontiers of this our world, and then continued his interests in science into this new field of the exploration of space. Dr. Lloyd V. Berkner, who is not only a scientist, but one of the scientist warriors of our time, a Rear Admiral in the Naval Reserve who worked his way up from rating through all ranks, who in his youth participated in the Byrd explorations of the Antarctic, now Chairman of the Space Science Board of the National Academy of Sciences and President of the Graduate Research Center of the Southwest, which is located in Dallas: Dr. Berkner will be our speaker and will speak on space sciences.

[Address of Lloyd V. Berkner was then presented.]

Chairman Stuart. It is now a great pleasure for me to present James E. Webb, Administrator of the National Aeronautics and Space Administration.

Mr. James Edwin Webb. Thank you. Harold. It's a very great privilege to be here. I'm proud that the National Aeronautics and Space Administration could be one of the sponsors of this group. I'd like to say we very deeply appreciate the work that Harold Stuart and the people here in Tulsa have done to make this meeting a success. We deeply appreciate the opportunity that the outstanding men who were in NASA long before I went there have had to come to know you, to let you see them, to let you test the quality of their thinking, and to let you see the kind of associates that we have in men like Lloyd Berkner on the Space Science Board to match the highly technological aspects of NASA operations.

Now, I have just a moment or two, because

I know that you are going on to a most important program. I know I had my say last night. But I would like to emphasize just for a very brief moment the tremendous importance of what Dr. Berkner has said in the transition we have now made through the use of modern rockets and modern space vehicles, from observation of a vast variety of phenomena in space through the hazy atmosphere of the Earth, and the strides we have now made that permit us to design and take out into space experimental apparatus to measure very precisely the specific phenomena desired. I think it's very important here to take one step further and ask yourselves here at this conference, what is it that Oklahoma, what is it that the Southwest can do now to help provide the brains to design the experiments that these giant space crafts will be flying eight and ten years from now. Because up to now, we have been drawing on a bank of scientific knowledge on the brains of a few men, to design the experiments that could go into vehicles weighing less than a hundred pounds in most cases.

Now, when you come to vehicles of the size Dr. Berkner has expressed, with a tremendous potential for carrying experimental apparatus, I think it's obvious that work should start now for the training, the evaluation, the research, the design of experiments for the period eight to ten years from now. We have to make a deposit in the bank if we expect to make the withdrawal later.

One more item I would like to mention and that is related to the statement that Mr. Hyland so cogently made at the end of this morning's conference. Namely, that we in this nation not only have to have an administration that can bring the various forces together, can map out and plan a program of this kind, that can, in the words of Mr. Dempsey, begin to match up the capacity of the various units in the government for cooperative endeavor and puzzle out the work, but can so schedule it that it actually fits together into a very thorough going piece, efficiently exercised and carried out: but further than that, we have to see that over a long period of time such a vast plan involving so many complex problems can actually be efficiently organized, administered and the results achieved. We have not in this country done nearly so well in carrying out vast enterprises of this kind as we have in many cases in making our hopes and dreams into such plans. So, I think it is extremely important to recognize here at this conference, as Congress is about to consider this program put forward by the President, that the commitment is not only to a program, to a concept, to an idea, but to a sustained activity involving many diverse elements of our nation, the industrial complex, the university complex, the world of science, the most brilliant minds we have, the economic analysis of the applications, the work by industry to bring those studies of the potential into actual realization by men and women around the world. But it is of the greatest significance that we find a way to bring all of these elements into a harmonious relationship that carries the work on. Here we do not have our normal means of adjustment in the price mechanism in the market place. We have much work to do to design the criteria by which such complex judgments, such complex interfaces, to use the word that has been expressed here, can actually do the job required if our democracy is to move forward. I think in conclusion I would like to say that, to me, this conference is a continuation of a movement started in this State of Oklahoma when the Frontiers of Science Foundation brought the Atoms for Peace program from Geneva here and showed it to some four hundred thousand people in Oklahoma. When, as a second item, the demonstration on our 50th birthday as a State of research as a process was put together, was so supported in this State, that more than 2400 people came off of the lines going through these wonderful exhibits that were brought here with the help of such men as Dr. Mervin Kelly, who will be here in a few moments as the chairman of this panel, and sat down at a little table with a professor from the university or school superintendent or a teacher, and said, "I would now, having seen this tremendous demonstration of research as a process, would like to know what it means to me. What university should I go to, what courses should I take, and so forth." So here following the Atoms for Peace show, following the Research as a Process demonstration, we now have the

National Conference on the Peaceful Uses of Space. So I think Oklahoma has not only set a first, it has set three firsts, and I think that Harold Stuart has some right to claim the second conference, although I must say I am not able to make a commitment, when Senator Magnuson sends the kind of telegram that he did—he's the chairman of the Appropriation Subcommitee that handles the money for the space agency.

At least I think you have earned the right to be in the competition, and I thank you very much for coming here. And I hope very much that any of you who feel your desire for more knowledge will let us know, will pursue the increasing flow of knowledge coming from the press; and I might mention to you, if I can get in a slight commercial for Dr. Berkner in view of the tremendous speech he has made here today, he has a book just out which is called "Science in Space," published by McGraw Hill. It's very valuable; it will cost you $7.50, but this is the kind of thing I think you need to look to, not the kind of Buck Rogers writing that you may even enjoy in the comics, but the serious kind of analysis of these problems represented by this book. So thank you very much; I hope to see you again, fellow travelers, fellow space travelers on the spaceship Earth; thank you.

Chairman STUART. I would like to introduce to you Dr. Mervin J. Kelly.

[Papers by J. R. Pierce, Elmer W. Engstrom, Herbert Trotter, Jr., T. A. M. Craven, Edward R. Murrow, Philip J. Farley, Harry Wexler, and Henri Busignies were then presented.]

Dr. MERVIN J. KELLY. As I told you earlier, the members of the panel each heard the presentations for the first time of the other members and, as this is a completely unrehearsed program, I am going to make an offer that may not be required; but I am going to first, before turning questions to the floor, give any panelist an opportunity to query any other one on anything they presented. So we now will give the panel an opportunity to question each other if they choose.

Dr. J. R. PIERCE. I wish to address a rather simple, I am afraid, question to the other members of the panel as they talked about satellite communications. I regard satellite communications as a very promising infant, but an infant still which takes a few steps, which sometimes stumbles and falls on its face. And I am so happy when it has some little success. It seems to me that my fellow panelists have seen in this infant as a fond father will see in the adult it may sometime be. And Messrs. Engstrom and Trotter have provided it with duties and obligations more than sufficient to a healthy man. Mr. Craven has said that it must not fall in the paths of unrighteousness, but must walk straightforward, one foot ahead, with its eyes on the heavens. Mr. Murrow has laid out for it a grand missionary of the world, telling us all to keep in mind that its life may not be worth living, and Mr. Farley has asked it to serve the nation immediately, to carry the burden of the weak on its back, and incidentally, to solve some of the problems of disarmament. Now, I ask you gentlemen, poor, poor infant, isn't its life going to be very difficult in such a developed world?

Dr. MERVIN J. KELLY. John, you have some people on the spot.

Dr. ELMER W. ENGSTROM. I'm not sure that I wish to respond to Dr. Pierce's observations, because I had in mind making some that were of a similar nature. First, I should like to make sure that no one goes away feeling that members of the panel, at least this member, favors a decision now between a low-altitude and a high-altitude satellite for communications so far as experimentation is concerned. In fact, we don't have that choice. There are two programs underway, one a low-altitude satellite, one a high-altitude satellite, and we need to carry on the experimentation with both of them because we need a more comprehensive appraisal of the situation than we have at the present time. What is important today is that we move as expeditiously as possible with all forms of experimentation. And this means not only the programs which the government will sponsor or have underway, but those programs also which industry will wish to conduct. And in this respect, cooperation is needed from the government because of the rocketry situation. There are two time needs that I would like to put in perspective for you. When do we need such a system? The first need relates to a matter of national prestige. For this we need it just as soon as it is humanly possible. The second need has to do with the commercial requirements of traffic. This may come at about the time we have the system in full-scale operation, or the system might slightly precede the full traffic need. But I think it's necessary to keep this in perspective because of the national prestige requirements that are involved here. An indirect reference was made to the cost of such a system. At such a time as when it can be fully loaded with traffic, it appears to engineers at the present time that this method of communications will be at least as favorable as the most low-cost method known at present for carrying messages from one point on ground to the other. Now, what is important is as we move along that at the right time we choose the system that will best serve all the peoples of the world. And the system should be one so that all of the nations of the world will have a need and a desire to keep it in operation. In other words, that it will not be subject to the political moves and maneuvers of nations throughout the world. They all ought to share in its use. They all ought to have a desire to keep it in operation. Now, some of the considerations that were raised today by panel members which serve as current thoughts on limitations, I'm sure will dissolve as we make progress, because this has always been the case and the end result which will be the right one will become clearer as we go along.

Mr. T. A. M. Craven. Mr. Chairman, I know that the Communications Commission has to be righteous, because the law requires us to be. And the Department of Justice sees to it that the industry follows along. It is our desire on the Communications Commission to get a coordinated effort by private enterprise started right away. We want them to start making traffic arrangements with other nations of the world and to deal with other nations of the world with respect to the owner of the birds themselves. Some of the nations will want ownership in the birds, others will not. They will want some rights to use. Now, another phase, I think we have to demonstrate the technical feasibility of the early systems, but I anticipate that will be done from research as time goes on. We have to replace these birds every so often and at that time you can introduce compatible improvements, though I don't worry too much about the ultimate system. We will arrive there and we will arrive there properly. It is fortunate that the earlier systems may have some shortness of life in the birds themselves. Now, with respect to the Department of State and the USIA, I agreed with the Department of State, but in this instance, I think it's necessary to take into consideration the economic factors that are involved.

Dr. Mervin J. Kelly. Thank you. Is there any other panelist—Mr. Busignies?

Mr. Henri Busignies. In the ICB system, the trouble is communication in international communications. And the first remark I would like to make, while we do have a good deal of good communications—we use the transatlantic cable, I'm sure you are all familiar with the relatively poor type of telephone communications which results from the use of A-check radio circuits. With all the best equipment and techniques which are now available, this, the quality of the transmission, is certainly very inferior to what you would like to get. And because of my work in this company, I travel throughout the world and I do use the telephone very often in all parts of the world. And the change to, or rather the addition of, a system which would have the quality necessary, the quality of the same over there that you can ask when you call San Francisco from New York or New York to London, or Paris from New York through the transatlantic cables, will change completely the aspect of international communication. The development of this traffic will be very substantial as a result of the use of a higher quality circuit. There are many many instances of people who after having used one of the existing circuits throughout the world that just hope that they won't have to phone again. They look forward to another communication of the same type with horror, not with satisfaction. Therefore, there is plenty to be done in that direction, and we have an opportunity with the satellite system to do something about it. Our company plans at its own expense to install a terminal for the relay satellite project in South America, where we do have our telephone companies operating there. We also hope that we will not have too often to change as a result of progress to ground installations, even though we would be willing to do so. There are many countries which do not want to change their communication terminal several times during the next 10 years. This will have to be very carefully considered before proceeding with that. Changes in the satellite to make the life longer, to make it better, that's all right. But we should agree on a system, on a worldwide basis, which would operate for a substantial length of time without too many changes and modifications. Communication industry is not used to offering these very frequent changes of systems.

Dr. Mervin J. Kelly. Thank you, Mr. Busignies.

Mr. Percy Carr, Iowa State University. I would like to address my comments to Mr. Murrow. In my opinion, Mr. Murrow doesn't need to be concerned about the blood-letting and blood-burning picture getting in the areas where the information will be detrimental to us. There are others who will take care of that. What we need to do is to have some system that will get behind these various curtains and we might be specific and talk about the Iron Curtain. There it seems as though technology has developed to the point where we might make a communications satellite that could carry pictures compatible to their systems over their area and get some of the favorable news into them directly. And in this case, since the television information will be carried on microwaves, which are highly directional, the people could avoid considerable jamming from the ground if they were informed as to how to make directional antennas and follow the satellite. In fact, my suggestion would be, the first message over would be a message on how to do this. And then they could follow the low-flying satellite illuminated by daylight; and this would be in the time of dark, so they would be in the dark and be very very hard to be policed. So they might very well get some information. In the light of this, I would like to ask Mr. Murrow if he wouldn't like to be the first one to support this program most effectively.

Mr. Edward R. Murrow. Mr. Chairman, I trust that I did not inadvertently cast myself in the role of an opponent of progress. That was not my intention. I think that the maturing years of this new system will be exceedingly difficult, because it is a difficult world in which we live. I agree that it would be ideal if this system of communications could be divorced entirely from the cut and thrust of political and psychological warfare competition, but until this minor planet is governed by an enforceable rule of law, I see no real possibility of that happening. Your question, sir, my technical knowledge goes to the extent of knowing that it could be done. The obvious difficulty is the political one as to whether the decision is made to intrude and whether there is any agreement possible now or in the future.

Mr. Percy Carr. It seems as though the programming of things that go into such areas could certainly be controlled without being called adversive censorship by agencies such as the FCC, your agency, and the State Department.

Mr. Edward R. Murrow. That's true.

Dr. Mervin J. Kelly. Any other questions.

Mr. Bill Mattox, Nathan Hale High School, Tulsa. I am addressing my question to the panelists in general. I would like to know if it would be possible to establish a system of satellites stationary such as presently planned for communications, only have it using a unit combining all three—that is, communications, weather, and navigation.

Dr. Herbert Trotter, Jr. I don't think a stationary satellite helps you from navigation.

Mr. Henri Busignies. The stationary satellite could be used for navigation, but with the stereographical system involving very detective, expensive containers to determine its angle. And that's why the people have decided to use the Doppler system instead.

Dr. Herbert Trotter, Jr. The other problem is it's a matter of weight, putting it up there, and the more you want it to do, the more it weighs and the more complex it is. And we at the present time will have enough trouble getting it up there to do one job at a time.

Chairman STUART. Dr. Kelly, what is the feasibility of jamming all three, of the weather, the communications and the navigation satellites and the possibility and the feasibility of doing that?

Dr. ELMER W. ENGSTROM. The possibility is very good of jamming, because if you can direct a signal at the satellite strong enough and unless the satellite has facilities in it to protect itself from being jammed, it is possible to jam it. And this will mean that for certain services there will have to be inbuilt sophistication to take care of this.

Dr. HERBERT TROTTER, JR. I think the problem here evolves around first-, second-, and third-generation systems for worldwide communication. The first-generation system, of course, is capable of being jammed, any of it is. But on the other hand, if it's used worldwide by all the peaceful world, any country that jams it, it is obvious at once which one is jamming, and I don't know of any nation that could stand world opinion to jam the communications of the free world.

Chairman STUART. Of course, the free world which we hope it always will be, but it would be possible then to destroy, as I understand, the navigation, communications, and weather in the event of a war.

Dr. HERBERT TROTTER, JR. You also could launch additional ones, too. And you would probably be prepared to launch additional ones for needed service.

Mr. HENRI BUSIGNIES. The lower-altitude satellite cannot be jammed very easily; that is, the Transit satellite, for instance, at five hundred miles would have to be within range of enemy territory to be jammed.

Dr. W. R. LOVELACE. I wanted to challenge Dr. Engstrom on jamming system.

Dr. MERVIN J. KELLY. Any other questions.

Mr. JOHN W. HERRICK, American Aviation Publications, Beverly Hills, Calif. I feel that Mr. Murrow is a little out of company; I want to shorten his name from "Director" to "Doctor" and then ask him a question, as doctor of communicated information. This has been quite a well-balanced and well-planned meeting, but there is one thing lacking and that's any discussion on space law. Don't you feel, Dr. Murrow, that before any of these problems that you are concerned about, the quality of our program, the image of the United States will actually all be settled when we find out what type of space law we will have and what type of treaties and agreements we will have?

Mr. T. A. M. CRAVEN. I know that the State Department will want to join in on this. If you are going to wait for the international lawyer to settle the problems of space law, we can get started. The commission has proceeded, I think the rest of the Government is proceeding, insofar as the orbit of satellites is for peaceful purposes. There will be no great objection.

Mr. PHILIP FARLEY. I would just like to expand on what Commissioner Craven said. We think the best basis on which to proceed is to try to find things which are in the general interest to do and thus establish a practice out of which law can be formulated. If we do it the other way around, we will get more controversy than we will results.

Mr. JOHN HERRICK. In connection with the navigation satellite, I'd like to ask a question of Dr. Busignies. Should we not consider more than one type of navigation satellite, though, because I think there are arguments on both sides which are at present unresolved. For instance, the ephemeris problem is a serious one, but the higher we put a satellite the less serious it becomes. At the present time, they publish the ephemeris of our Moon, which is a natural satellite, for at least two years in advance and they think they can do it for two to four hundred years in advance. So if we would put a satellite up higher, the ephemeris would become relatively easier and at some point it could be predicted for a year in advance. While the complexity of angular measuring equipment on the ground may seem large, it is not necessarily more complicated or difficult than some of the Doppler analyzing computer things, is it? And also, the simplicity of the satellite aloft just as a sort of a beacon or directional signal, the constant frequency is not a requirement in the high satellite and only a few satellites are necessary, while in the low-flying transit system, many are necessary. The FCC would be happy to have fewer satellites.

Mr. Henri Busignies. Well, I'd like to comment by saying first that my greater description of the Transit satellite and of the work done is because it is an existing program which is going to result in a working system in the relatively near future, and it seems to those who study the development of it, and I am quite open on the subject because I didn't and I am present up here. At the beginning, it was simpler to approach it from the use of the Doppler system. Later on, you may be completely right, that when higher, much higher satellites can be used, I don't mean stationary because those would be moving all the time by their control system, and therefore would be subject to shifts and errors which would be difficult to predict. But the others, say 10,000 miles or 15,000 miles, could later on, with a powerful transmitter simplifying the receiving system on the Earth, could later on successfully be used with ephemeris. They are not eliminated I am sure from a discussion, but the time is not quite ready for them yet, because of lack of technology to place them there and so on.

Mr. Charles J. Koch, The Martin Co., Baltimore, Md. Dr. Engstrom, could you give us an estimate of the weight of your 24-hour television broadcasting station that would have hemispherical coverage on you last slide that you showed?

Dr. Elmer W. Engstrom. No, sir, I cannot, because it will take something in the order of kilowatts up to ten to have limited coverage and more, of course, to have hemispherical coverage. And I indicated that this is substantially more distant in the future than what we can contemplate for a communications satellite. Not only when we come to the weight of the transmitter but it's unlikely that we can derive power from the Sun for this purpose. So we will have to carry our own fuel.

Dr. Mervin J. Kelly. Any other questions?

Mr. E. Allen Cook, Operations Research Chief, Ross-Martin Co., Tulsa. This may be a partial answer to the double-barreled question I have. Dr. Engstrom, if I understood you, you said that under full utilization, the cost for telephoning might be such that I could dial home for a dime from the corner drugstore. I don't know if you meant between any two points it would be cheaper than the present method. Let me make my other comment, because it's related, and ask Mr. Murrow. Apparently radio TV-FM program commands much better circuits with its budget than do private telephone calls. One wonders about the over bombardment of the individual with information now in the form of all the things that impinge on his senses and demand his loyalties. Do you think we are ever going to have a problem in this area?

Dr. Elmer W. Engstrom. Well, first let me explain what I meant, if I was not clear. What I intended to say was that when one computes the cost of the equipment, the cost of getting the satellite into place, the cost of maintenance of the system, that this turns out per channel mile of being favorable with other means of communication. I made no reference to what it would cost you to get a radio message or a telephone message from one point to another. Now, this is all that is necessary for the system designer to know, that he is on a favorable route to get a right answer.

Mr. Edward R. Murrow. I think the only comment on the second part of the question would have to be that the ear of the world is being assailed with more and more sound and the difficulty is to sort it out.

Col. Martin Menter, Federal Aviation Agency. I wonder, have there been any thoughts as to whether or not the commercial type satellite is subject to taxation by a subjacent sovereign or perhaps the communication itself subject to possible actions for slander. I mean that in a serious vein; it's not a facetious question.

Mr. T. A. M. Craven. What would be the difference between that and the present radio systems?

Colonel Menter. Well, I assume you have under the present intenational radio system, you have already a series of agreements to cover this and on a satellite I don't know; I'm asking as to whether or not the satellite perhaps would transverse more sovereignties than you cover by an international radio system. I assume under the latter you do beam it to a particular place. Perhaps it's too early, really, to even think of it.

Dr. HERBERT TROTTER, JR. If they are stationary satellites, they may be out over the ocean anyway, so they are in free territory.

Dr. MERVIN J. KELLY. Any other questions.

Mr. GEORGE H. STONER, Program Manager, Dyna Soar-Boeing Co., Seattle, Wash. Conspicuous by its absence in this panel discussion has been any mention of the role of men in connection with maintaining the systems involved. General Ritland mentioned this possibility this morning. I know that the telephone systems have become very adept at maintaining submarine cables for years and years without maintenance and remote stations. But I imagine it is a great convenience to at times go and repair the equipment. Does the panel wish to comment on the economics of manned maintenance of the equipment they have been discussing?

Dr. J. R. PIERCE. I would like to comment on that if I might. It seems to me a day beyond my imagining when it would be cheaper to shoot a man up to repair a satellite than it would be to shoot up a new satellite.

Dr. HERBERT TROTTER, JR. You might say one thing about the satellite. If it ends up that we can dial any phone in the world, instead of being able to dial only the wrong number locally, or then with the event of long-distance dialing we can dial the wrong number in any place in the United States, maybe some day we can dial the wrong number any place in the world; we have more latitude to make mistakes.

Dr. HAROLD S. BRAHAM, Aerospace Corp., Los Angeles, Calif. I think the point that Dr. Engstrom made about the prestige value of putting the communication satellite up is real important. It seems clear from the comments, economically and technically it would be possible to do so in the '63 to '65 period. But I think an important consideration is that we do it as soon as possible, because if we do it in '65 and we could have done it in '63 and the Russians do it in '64, I think we will be very unhappy about the whole thing. So I would like to address a question to the proponents of the high-altitude, medium-altitude satellites: Assuming that there was enough national priority and assuming that the boosters were available, what time scale would one have an operational system? I am not talking about an experiment or a few of them in there, but something that would be useful something like 24 hours a day or close to it.

Dr. HERBERT TROTTER, JR. Would you define your question. By "useful", you mean useful between New York and London, or do you mean——

Dr. HAROLD S. BRAHAM. Transatlantic. Transatlantic, let's say, an operational transatlantic.

Dr. HERBERT TROTTER, JR. Only transatlantic or do you want a worldwide system? I think this is what it comes down to. It makes a lot of difference which question you ask. If you want a way to supplement the cables between New York and London, the answer is one way.

Dr. HAROLD S. BRAHAM. Let's say both ways.

Dr. HERBERT TROTTER, JR. If you want both ways——

Dr. HAROLD S. BRAHAM. In other words, I think that the impact of a transatlantic system would certainly be the important thing and then you could have it grow to the international one. I think, for two reasons, it all would be real impressive and excellent, and would have a great impact on world opinion, and I think that the second thing, it would be a real useful thing. I think they are correlated and if you had a transatlantic system in, I am sure you could at the same time get some coverage to other points. In other words, if you had a transatlantic system in you could probably get, for example, the 24-hour one you can get coverage in South America. This would be valuable. You can get coverage to certain parts of Africa with the system that Dr. Pierce is talking about. You probably would not get continuous coverage to the whole world, but you would get coverage for certain periods of time. In other words, you might get 24 hours, or close to 24 hours, on the transatlantic system, but you might get something like five hours to Africa or a couple of hours to South America, and this would be important. So, I think—I agree there is a great area in there, but almost the same complete coverage on transatlantic coverage worldwide. I want to get an idea of the time scale; I think it's a chief point to find out in making a decision as to which system makes the most sense as to the time scales involved, because I think the eventual system, you probably will have combinations of the two. I think we would like to get an idea when the first one would be developed.

Dr. HERBERT TROTTER, JR. I think the answer to this would involve an argument going into many hours. I think this is some of the big arguments that have gone up in the past. Certainly for a quick experimental one there is no argument, the low one does. With the low one you need to put up, according to Bell's argument, about fifty. This is quite a number for worldwide systems, plus if you want a worldwide system you probably would have to build—I don't know, I am not sure of the answer, probably a couple hundred of their big moving antennas with a stationary system, then you wouldn't need this.

Dr. MERVIN J. KELLY. I think this is a good point at which to suspend the questions, time is getting on, so I am going to turn this meeting back to Mr. Stuart.

CHAIRMAN STUART. Thank you, Dr. Kelly, Dr. Pierce, Dr. Engstrom, Dr. Trotter, Mr. Craven, Edward R. Murrow, Philip Farley, Dr. Wexler, Mr. Busignies; it was very fine. We appreciate the wonderful panel you had this afternoon. It was most informative and most interesting, and we want you back again.

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